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DUSTRY AND
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JUNE, 1939

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7—Journal Section of
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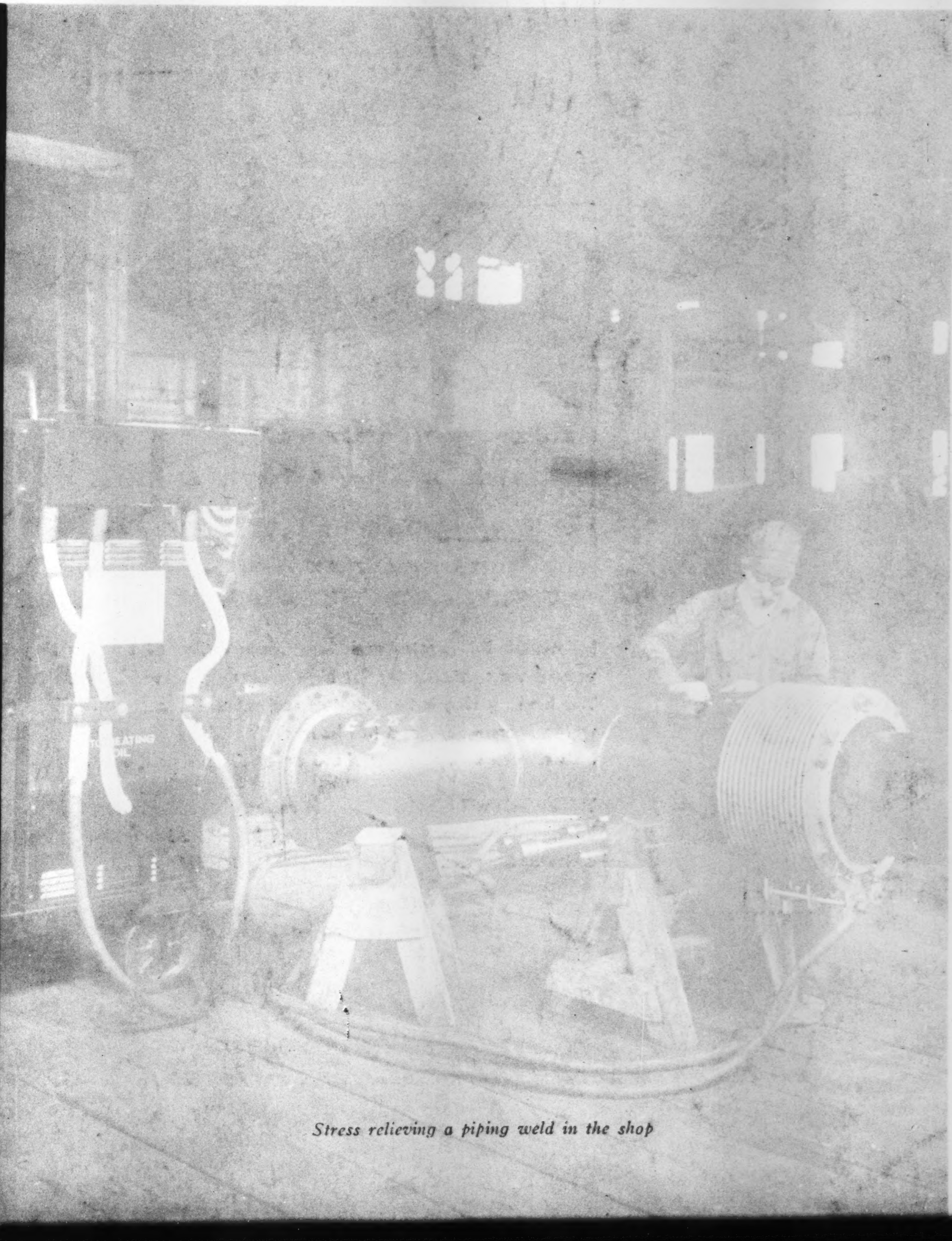

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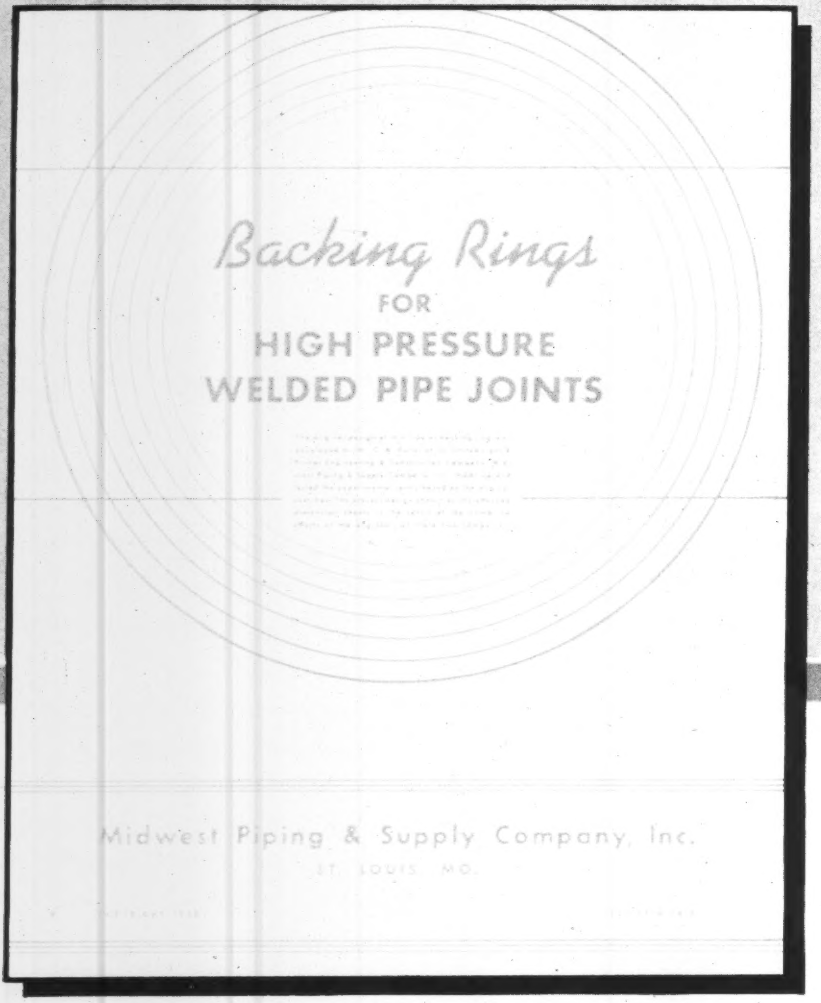

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Bulletin 38-B illustrates and describes a design of backing ring that has proved very satisfactory for high pressure pipe welds made in the field. This backing ring is the result of several years' research in high pressure welded connections and has been confirmed by numerous joint destruction tests as well as by successful use under difficult field conditions.

This bulletin will gladly be sent to anyone interested who requests it upon a business letterhead. Simply mention Bulletin 38-B and address the main office at St. Louis.

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The Editor's Page

■ **Drug chains** led in air conditioning installations last year, according to a survey of air conditioning prospects in the chain store field recently completed by *Chain Store Age;* 5.9 per cent of the chain drug stores were air conditioned, bringing the total with air conditioning up to 26.7 per cent of all chain drug stores. . . . Apparel stores were second, 5.1 per cent being air conditioned to bring the total up to 23.8 per cent. Restaurant chains were third, with 4.2 per cent conditioned in 1938, and with a total of 18.6 per cent. Shoe chains conditioned 1.6 per cent of their stores, making their total 12.5 per cent. . . . Of the major fields in which mass distribution operates, this leaves variety and department stores. While the first of these conditioned only 1.5 per cent of their stores in 1938, making the total 4.7 per cent, they spent the largest sum on the work—$1,010,700—according to the survey. . . . In all fields, the chains conditioned 1.4 per cent of their stores last year to bring the total conditioned to 6.1 per cent.

■ **The valve**—indispensable to modern industry and modern civilization—is to receive tribute at the Museum of Science and Industry, Jackson Park, Chicago. Representing all valves from the tiniest spigots to gigantic sluice gates will be a 17 ton, 72 in. valve, the gift of Crane Co. to the museum. . . . Water from streams, lakes, oceans, and bays all over the world will play a role in a dedication ceremony in which Dr. Philip Fox, director of the museum, and Charles B. Nolte, Crane's president, will officiate. The dedication rite will symbolize the control exercised by valves over liquids and gases wherever they have been put to the service of mankind.

■ **Some day**—perhaps 20 years from today—man will not only live in an air conditioned cycle, but his life span will be increased by the healthful living conditions brought about by air conditioning. He will live in an air conditioned home, eat in an air conditioned restaurant, be amused in an air conditioned theater, ride to work in air conditioned subways, trains and buses, drive an air conditioned car, and work in an air conditioned office.—Dr. Willis H. Carrier, at the dedication of the Carrier "Igloo of Tomorrow" at the New York World's Fair.

■ **P. Y. Danley,** Westinghouse Electric & Mfg. Co., was elected president of the Air Conditioning Manufacturers' Association at its annual meeting last month. . . . Other officers are S. E. Lauer, York Ice Machinery Corp., vice-president; P. A. McKittrick, Parks-Cramer Co., treasurer; and W. B. Henderson, executive vice-president. . . . The board of directors includes J. F. G. Miller, B. F. Sturtevant Co., chairman; Stuart Crocker, General Electric Co.; E. T. Murphy, Carrier Corp.; J. A. Harlan, Nash-Kelvinator Corp.; J. M. Fernald, Baker Ice Machine Co.; E. D. Kirk, Vilter Mfg. Co.; and the association's officers.

■ **Factory sales** of mechanical coal stokers for the first quarter of 1939 increased 13.4 per cent over the same period last year, according to a report released by the Department of Commerce based on data furnished by 101 manufacturers for 1939 and 112 manufacturers for 1938, the Committee of Ten points out. The total sales of all sizes and types of stokers in the first three months of this year were 9987 units compared with 8807 in 1938. . . . Eleven of the manufacturers reporting in 1938 have discontinued making stokers.

■ **It was announced** on this page last month that publication of a series of tables of the psychrometric properties of air for various barometric pressures, compiled by William Goodman, would start in this issue. Space limitations and the requirements of our editorial balance, however, have necessitated postponement of this material. . . . The tables will give the properties of air for barometric pressures from 22 to 32 inches of mercury. With a few exceptions, they are arranged in a form and used in the same manner as those for normal barometric pressure published in our January, 1938, number.

■ **Observation portholes** of "Pyrex" glass both above and below the water line permit visitors at the Kewanee exhibit at the New York World's Fair to see a boiler actually making steam. The steam bubbles can be seen forming in the boiler and bubbling up through the water into the steam chamber. So that the inside of the boiler will remain untarnished and its appearance will be preserved for better vision, the exhibition model was especially built of monel metal throughout, including the tubes. . . . Kewanee Boiler Corp. has announced a $90,000 expansion program for installation of equipment to manufacture high pressure welded boilers, it was reported last month.

■ **Contracts have been let** by Battelle Memorial Institute, Columbus, Ohio, for construction of a new laboratory to take care of the expanding volume of research, according to Director Clyde E. Williams. American industrialists are becoming increasingly research minded, he says, and the nation's facilities for research will have to be greatly expanded in the immediate future. . . . The new construction consists of a wing to provide approximately 50,000 sq ft of space on five floors in which will be chemical and metallurgical laboratories, photographic and metallographic departments, physics laboratories, and a large industrial laboratory. Constant temperature and controlled humidity rooms are to be provided for chemical and metallurgical studies.

■ **James W. Follin,** who has been associated with the technical work of the Federal Home Loan Bank Board, has been appointed managing director of the Producers' Council administrative office in New York City, according to an announcement last month by Russell G. Creviston, president of the council and director of advertising and sales promotion for Crane Co. . . . The council is an association of nearly 70 representative manufacturers and associations of manufacturers of building materials and equipment, and for 18 years has been affiliated with the American Institute of Architects to foster a closer and more professional relationship.

■ **President Mathis** of the National Association of Fan Manufacturers announced last month the following committee appointments for the ensuing year: Bylaws and rules committee, J. M. Birkenstock; credit committee, H. S. Whiting; engineering committee, G. S. Polk; finance committee, W. Gardner; legislation committee, E. B. Freeman; membership committee, E. Szekely; publicity committee, J. M. Frank; standards committee, F. Herlan; statistical committee, F. Herlan; trade relations committee, J. E. Truitt; transportation committee, O. B. Coblentz; NAFM representative on NFPA blower systems committee, J. O. Lennon.

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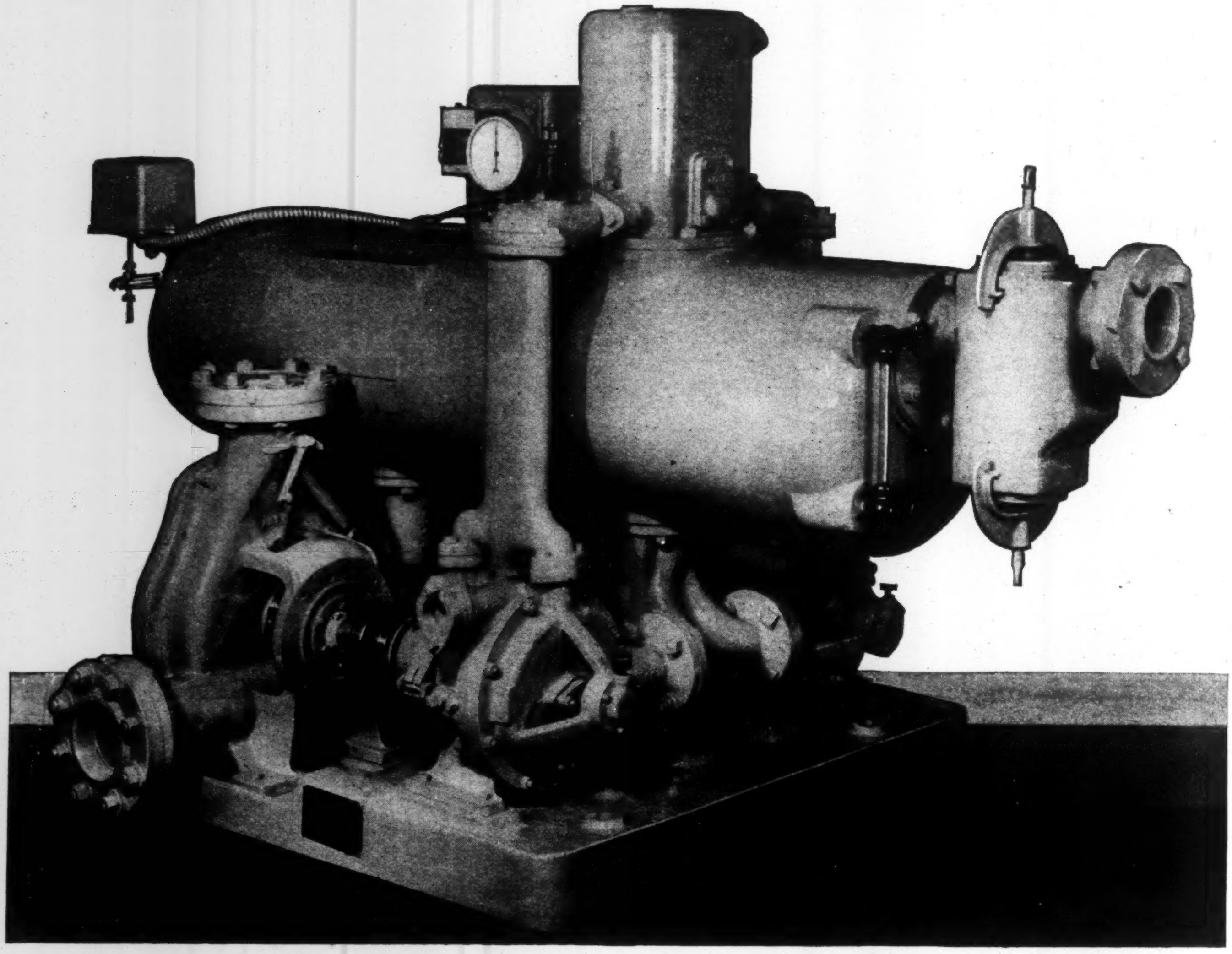
Bulletin Section 405

Where Heat Must Not Fail— Install this SAFE Heating Pump!



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Heating·Piping
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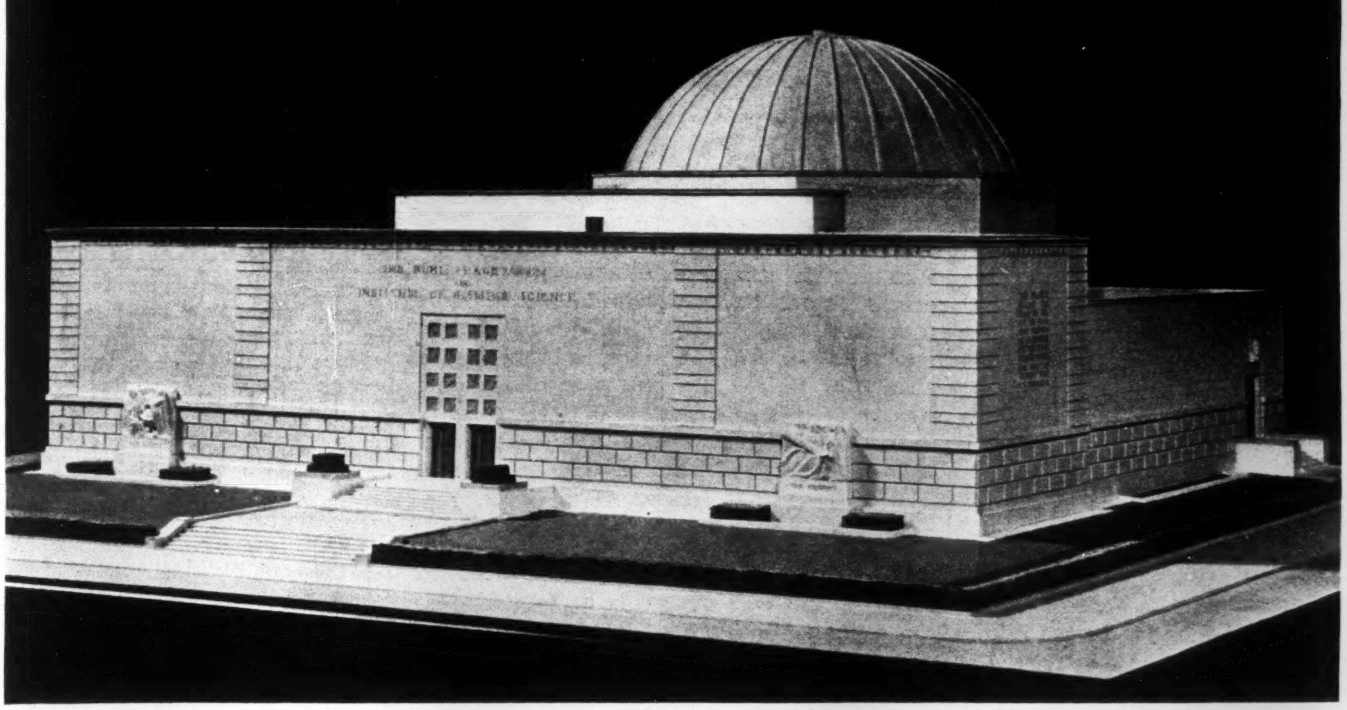
Vol. 11, No. 6 • June, 1939



Model of the new Buhl Planetarium and Institute of Popular Science

Heating and Air Conditioning Pittsburgh's Buhl Planetarium

By George S. McEllroy* and Theodore F. Rockwell*

THE Buhl Planetarium and Institute of Popular Science, now nearing completion in Pittsburgh, is the fifth such structure in the United States, there being planetaria in Chicago, Los Angeles, Philadelphia, and New York. The picture of the model of the building shows its general shape and the 70 ft diameter dome which forms the ceiling of the planetarium chamber. The building has a total volume (architectural cube) of 1,036,000 cu ft, of which 675,220 cu ft represents internal usable public and private space.[1] In addition to the planetarium chamber, the public space includes two exhibition galleries and a lecture room on the first floor, three exhibition rooms and amateur work rooms on the ground floor, and a telescope room on the third floor. The front wall of the telescope room is just visible over the front parapet wall in the picture of the model.

The planetarium chamber will be used for popular lectures on and demonstrations of the solar system. The hemispherical steel sheet ceiling will serve as a screen upon which the "stars and planets" will be projected from the planetarium instrument situated in the center of the room. Semi-permanent exhibits demonstrating the fundamentals of physics and astronomy will be placed in the galleries on the main floor. The use of the ground floor galleries has not yet been definitely determined, but they probably will be used from time to time to display products of local industries. The lecture room is provided with a permanent screen, a complete projection room, and a well fitted lecture and demonstration table, and will be available to scientific and technical organizations and for lectures of popular interest. In the telescope room there will be a 10 in. telescope which the public may use to study the stars and planets. Because of space limitations, the telescope barrel will be fixed in a horizontal position and a mirror will be used to reflect the sky. A portion of the roof is designed so that it may be rolled back to expose the mirror.

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*Consulting Engineer.

[1] Determined from inside dimensions of rooms.

Slightly less than a tenth of the finished floor area and a tenth of the usable internal volume has been taken up by mechanical and electrical equipment[2] common to public buildings of this type. Special services peculiar to this building account for another tenth of the floor area.

The consulting engineers discuss the design of the heating and air conditioning systems for Pittsburgh's new Buhl Planetarium and Institute of Popular Science, the fifth such structure to be built in the United States. . . . The cooling load analysis indicated the engineering advisability of well water for precooling, and the storage of chilled water for meeting peak loads; these and other details of the installation are treated in full in this informative discussion

Factors Influencing Heating Design

The important factors influencing the design of the heating and cooling system were, briefly, the following: (1) The building has no windows except a few in offices and shops. (2) The heavy load bearing masonry walls. (3) The intended use of various spaces—exhibition, astronomical demonstration, lectures, offices, and shops and other services. (4) Interior finish. (5) Relative location of rooms to main fan room.

Due consideration, together with a study of operating experience in the Philadelphia and New York planetaria, led to the final division of the load into separate systems as shown in Table 1.

The final decision to group the rooms in this way was greatly influenced by the information contained in Table 2, which shows the calculated heat losses of the principal rooms for local design conditions. The last column in this table expresses the ratio of heat loss to room volume. Because of the wide variation of this ratio, separate systems are desirable for proper temperature control.

There are separate supply and exhaust fans for each system, the discharge of the exhaust fan being connected to both the intake of the supply fan and to a vent duct discharging through roof ventilators. Throttling of the return air damper will cause a pressure rise sufficient to open back-draft dampers and allow return air to be vented to outside. Exhaust fans were selected to make return of air more positive, to make the pressure of outdoor air and return air more nearly equal at the point of mixing, and to reduce the resistance head on the supply fan.

The combination of small heat loss and usual volume of air supplied produces a low temperature at the supply grilles, as shown in Table 3. Naturally, not much reheating surface is required to attain this final temperature. To provide flexibility in temperature control, only single row reheating coils were used, an additional refinement being the use of two steam control valves in parallel for each row of tubes.

Several factors influenced the decision to install a unit air conditioner for the office floor—the library and reception room have no windows; the cleanliness of filtered air; and the peculiar location of the offices, which will probably make gravity ventilation ineffective in summer. In winter, radiant front convectors under control of individual room thermostats will handle heating requirements. The conditioner will circulate tempered air only.

Complications in control were avoided by deciding on a fixed quantity of outdoor air for both winter and summer. This volume was set at 300 cfm, which is ample for the expected occupancy of the offices.

The unit heater at the main entrance is for the purpose of preventing cold drafts across the main gallery floor because of infiltration through the doors. The unit is concealed in a specially designed chamber over the

Table 1—Division of Load

Gallery F-1	Fan No. S-1
Galleries G-1, G-2, G-3 Special Exhibit Room	Fan No. S-2
Lecture Room	Fan No. S-3
Planetarium Chamber	Fan No. S-4
Gallery F-30	Fan No. S-5
Shops	Unit Ventilator No. 1
Amateur Rooms Photo Rooms	Unit Ventilator No. 2
Main Entrance	Unit Heater No. 1
Rear Entries	Unit Air Conditioner No. 1 Radiators
Telescope Room	Radiators

Table 2—Heat Losses

Room	Mbh	Btu per Hr per Cu Ft
G-1 Gallery	45.2	1.39
G-2 Gallery	27.4	1.11
G-3 Gallery	62.1	1.27
G-4-5 Toilet	3.3	1.42
G-8 Special Exhibit	21.0	1.86
G-17-18 Toilet	3.3	1.42
G-24 Wood Shop	9.7	3.45
G-25 Receiving	9.0	4.30
G-26 Mch. Shop	24.5	1.93
G-29-30 Photo & Dark	10.8	3.40
G-35-6-7-8 Amateurs	30.0	2.40
F-1 Gallery	212.7	1.56
F-17 Storage	5.9	9.84
F-18 Lecture	67.9	1.72
F-20-7 Corridors	24.4	2.95
F-30 Gallery	72.0	1.99
F-45 Planetarium	149.9	1.43
S-5-8 Hall	3.1	1.64
S-9-10 Toilet	0.6	1.36
S-12-13 Offices	15.0	5.14
S-14 Files	5.4	7.30
S-15-16 Toilet	1.4	0.95
S-17 Storage	1.1	1.36
S-18 Coat Room & Toilet	9.4	9.46
S-19 Office	14.0	4.20
S-20 Office	7.5	4.19
T-1 Observation	19.9	9.15
T-11 Stairwell	12.8	9.85
T-38 Stairwell	12.8	9.85
M-14 Projection	2.4	0.88
	884.5	

---

[2] Does not include elevators which are considered as circulation space.

revolving door housing and the air is discharged downward through grilles in the ceiling of the vestibule. The fan motor will be controlled from a thermostat placed behind the return grille built into the vestibule.

Pneumatic temperature control is used throughout the building except for two small unit heaters. The fan systems are controlled from insertion type thermostats situated in the return air ducts near the fans. When the fan is started, the outdoor air damper opens to its minimum position, which is maintained until overheating occurs. Upon a rise in temperature of return air, the duct thermostat first throttles the steam supply to the coils and then opens the outdoor air damper to a wider position as required. Limiting devices include a thermostat on the downstream side of the tempering coil to prevent freezing of condensate and one in the discharge of the supply fan to prevent delivery of air at less than 60 F when the room requires cooling.

Heating steam will be furnished the planetarium from a branch library across the street.

Cooling Loads Analyzed

The original design for the Buhl planetarium contemplated cooling for only the planetarium chamber, the lecture room, and the offices. The outside air intakes were made large enough to pass all the air handled by the fans and it was felt that because of the heat capacity of the structure, ventilation with night air would provide all the cooling effect needed in the other spaces. As the design was nearing completion, however, the owner suggested that future plans for the use of the building would include a special exhibit in the octagonal room on the ground floor. A lecturer will conduct groups of people through the exhibit, and if large numbers of people assemble in these ground floor galleries at one time, cooling may become desirable. Consequently cooling coils were added to the basement group (Fan S-2).

Table 3—Fan Capacities

Fan No.	Group	Volume of Space	Heat Loss	Fan Capacity	Air Changes per Hour	Required Temp. at Grille	Minimum Outside Air
		Cu Ft	Mbh	Cfm		F	Cfm
S-1	Main Gallery	136800	213	14500	6.36	84	3000
S-2	Ground Floor Galleries	116980	156	11000	5.65	83	2400
S-3	Lecture Room	39400	68	5750	8.70	81	3000
S-4	Planetarium	105200	150	12200a	6.05	81	5500
S-5	East Gallery	36300	72	3800	6.30	88	1000
Unit A.C.	Offices	15400	b.	2200	8.56	....	300

[a] Only 10,600 cfm to planetarium chamber. Remainder to projection room, organ chamber, and to space over inner dome.

[b] Heat supplied by cast iron convectors; air for ventilation only.

Table 4—Summer, Winter and Design Cfm

Office	Winter Ventilation Cfm	Summer Cooling Cfm	Design Volume Cfm
Curator	330	540	450
Secretary	180	300	300
Library	360	330	450
Reception	360	315	450
Lecturer	150	360	250
Lecturer	150	360	250
	1530	2205	2150

Considerable study was devoted to the cooling loads in the case of the planetarium chamber, and the heat gain was calculated for a 24 hr period at intervals of one hour, based on hourly temperatures from the local weather bureau for a hot day in 1936. No infiltration was included because of lack of windows. For solar radiation effect the temperature differentials recommended in Chapter 8 of the ASHVE Guide 1937[3] were used. It was further assumed that the walls would have a heat lag of 12 hr and the roof a lag of 6 hr. The calculations further assumed that two shows daily will be given, one from 2:30 to 3:30 p. m. and the second from 8:00 to 9:00 p. m., daylight saving time, that there will be 400 occupants, and that the minimum outside air requirement per person is 1 lb per min, or 13.5 cfm.

The plotting of the components of the cooling load for this system indicated that heat gain from the outside by transmission and solar radiation will have but little effect on the total load and further that it will be a load of high peaks of short duration. Such a load suggests a system of storing refrigerating effect.

The conclusions drawn from the detailed calculations of heat gain from outside to the planetarium chamber were applied to the solution of the problems in the lecture room. This room has an exposed ceiling and exposed west and north walls, the west wall being parallel to the long axis of the room. Sun effect on the roof had to be considered but the sun effect on the west wall will not be in phase with any other components of the cooling load occurring during the normal use of this room.

From the control standpoint the office group presented a problem that was more complex. Six rooms are conditioned, two with eastern and ceiling exposure, two with no outside exposures, and the other two with western and ceiling exposure. The outside rooms have windows, hence the east rooms will have a morning peak and the west rooms an afternoon peak. Zoning of the duct work seemed to be the simplest solution of this control problem.

In a year round air conditioning system, the air quantities for winter and summer seldom coincide when computed on the basis of heat loads and the permissible rise or fall of air temperatures. To overcome this difference in this case, some consideration was given to a two speed fan, but it did not appear that the improvement in results would justify the added cost and complication. Accordingly the compromise of Table 4 was adopted.

As stated before, two rooms, the library and reception room, have no exposure. Consequently the cooling loads will not vary because of movement of the sun and these rooms should receive substantially a constant amount of air all day. To overcome the effect of throttling by the zone dampers, two supply grilles were placed in each of these rooms. One in each room is connected to the east zone and one to the west zone. Each grille was sized to pass 225 cfm; thus, as the cooling effect is shifted from the east to the west zone, the total air delivered to these rooms will remain approximately constant at some figure less than the 450 cfm shown in Table 4. The total air volume will not cause objectionable air movement in winter when the zone dampers are not in use.

---

[3] The building plans were prepared during 1937.

The decision to provide cooling for the basement group was made after the plans had been substantially completed. No definite information was available on the number of occupants which might congregate in these rooms at one time. The possibility that large crowds might be attracted during hot weather by some special exhibit was considered, but it did not seem advisable to provide extra capacity for such rare conditions.

After several trial selections, a coil was finally specified for this group which has a rated capacity of 208,000 Btu per hr at a mean temperature difference of 16 deg. This is sufficient to care for 2400 cfm of outside air, 20 kw of lighting, and 150 to 160 people. These rooms are entirely below ground and any heat flow through walls and floors will be outward rather than inward.

Storage of Refrigerating Effect

The cooling loads are summarized in Table 5. That the load factor on this system will ever be 100 per cent is highly improbable, but until the system has been in operation, statements of load factor would be but hazardous guessing. Load curves for simultaneous operation of the entire connected load on a day of 95 F dry bulb and full occupancy in all rooms were drawn for a likely schedule of use of the several rooms for use in the analysis. This graph showed a possible addition of the several items of the cooling load. There are, however, several good reasons for avoiding a recommendation that money be spent to install cooling equipment with an instantaneous capacity of 86.4 tons. They are:

1) The loads graphed were the maximum for each of the respective systems, and outdoor temperatures do not remain stationary at their maximum level for 10 to 12 hr.

2) A definite schedule for use of the lecture room has not been established. That this room will often be scheduled for use on extremely hot days is unlikely. When such conditions do occur, staggering of the time would correct such high peaks.

3) Outdoor temperatures of 95 F are infrequent and of short duration in Pittsburgh. Examination of the dry bulb temperature records of the local weather bureau revealed that temperatures of 95 F or higher have been reported for only 39 days in 25 years or about 1½ days per year. For temperatures exceeding 92 F the figures are 92 days, or 3⅔ days per year.

4) The peaks are of short duration, and the storage of chilled water would enable smaller compressors to carry these peaks. Cooling storage water will also improve the load factor for smaller compressors and reduce demand charges for electrical energy.

Table 5—Summary of Cooling Loads

FAN NO.	GROUP	LOAD IN MBH		
		SENSIBLE	LATENT	TOTAL
S-2	Ground Floor Galleries	140.0	68.0	208.0
S-3	Lecture Room	167.0	114.5	281.5
S-4	Planetarium Chamber	331.0	166.0	497.0
Unit A.C.	Offices	42.1	10.1	52.2
	Total	680.1	358.6	1038.7

1038.7 Mbh = 86.4 tons

COOLING BY WELL WATER

S-3	Lecture Room	83.5	24.5	108.0
S-4	Planetarium Chamber	127.0	40.0	167.0
	Total	210.5	64.5	275.0

275 Mbh = 22.9 tons

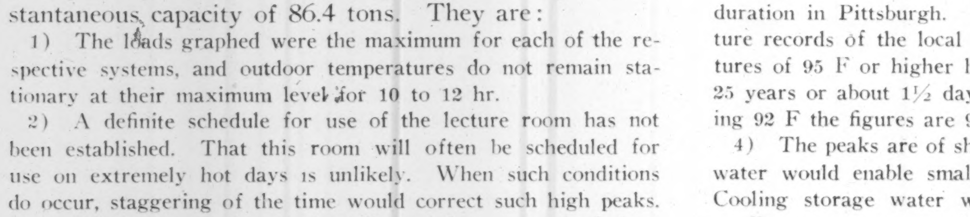
INSTANTANEOUS COOLING CAPACITY

	PEAK PERIOD					
	1 HR		2 HR		3 HR	
	MBH	PER CENT	MBH	PER CENT	MBH	PER CENT
Well Water	275	26.3	275	30.5	275	32.3
Compressors	480	46.0	480	53.4	480	56.3
Storage	290	27.7	145	16.1	97	11.4
Total	1045	100.0	900	100.0	852	100.0
Peak Load (see above)	1039	......	1039	......	1039	
Per Cent Capacity	101.0	......	86.6	......	82.0	

Well water was also investigated in the interest of economy, and after consulting building managers in the immediate vicinity who had wells, and a local well drilling contractor, the drilling of a well was authorized by the owner. This well was completed in October, 1937, and tests indicated that it could be relied upon for a sustained capacity of 60 gpm at 57 F at the well.

Water at a temperature of 57 F is suitable for precooling the air, but the temperature is not low enough to cause the necessary dehumidification. It was then decided to divide this well water between the planetarium chamber and the lecture room in rough proportion to their sensible heat

The chilled water and well water cycles



loads (planetarium 33 gpm, lecture room 27 gpm) for first stage cooling. From these first stage cooling coils, where the water will be heated about 10 deg, it will be pumped to the condensers, entering at about 70 F. The city water frequently rises to higher temperatures in the summer and this cooler water will thus effect some saving in power over the use of city water for condensing. During operation for chilling storage water, the well water will go direct to the condensers, thus maintaining a still lower head pressure.

The size of the storage tank for chilled water resulted in a compromise between the theoretically desirable amount of storage water, the estimated cost of tanks and the space available. A tank of 3500 gal was specified and it is intended to cool this water to 35 F before the cooling coils go into operation. This temperature will allow about 10 deg of storage or a total of about 290 Mb. For a 2 hr peak this would be 145 Mbh and for 3 hr, 97 Mbh.

Two 20-Ton Compressors

When this information had been assembled, the use of two 20 ton compressors was decided upon. The reasons were:

1) The price of two small machines compared favorably with the price of one 40 ton machine with a two speed motor.

2) The local utility places a limitation on starting current of 200 amperes for all motors supplied from its 200 volt network. This allows a 20 hp motor to be started with an across-the-line starter, but the larger motor would require a special starter.

3) With the help of the well water and the storage tank, one 20 ton compressor will be able to handle the total load most of the time. Thus, standby compressor equipment will be available for all but the few days a year when maximum loads occur.

4) Because of (2) and (3) there will be lower demand charges and better average energy rates for many months during future cooling seasons.

The cooling capacities are summarized at the bottom of Table 5 for peak loads of 1, 2 and 3 hr duration. These capacities are also expressed in per cent of the maximum possible load as taken from the upper portion of Table 5.

The compressors have separate water coolers to avoid difficulties with parallel operation of compressors. Water is pumped from the tank through either or both water coolers and back to the tank by one of the pumps. Separate pumps are provided for each of the cooling systems to pump chilled water from the tank to the respective cooling coils.

Chilled water coils as opposed to direct expansion coils were chosen for the following reasons:

1) The desirability of stored cooling effect favors water coils.

2) This arrangement permits the two compressors to serve the four separate cooling systems, any combination of which may be in operation.

3) The system requires less refrigerant, and possibility of leakage is also reduced.

Control of Cooling System

Tentative cooling coil selections soon revealed that a bypass around the coils would be desirable to attain the necessary flexibility of dew point control from no load to full load, and consequently the bypass was adopted.

As during the heating season, the air temperature will be controlled from a thermostat in the return air duct when cooling. One of the features of the control will be the resetting of this duct thermostat by a thermostat situated in the outside air intake which will raise the inside dry bulb temperature as the outdoor temperature rises. So that all possible advantage may be taken of outside air for cooling, the outside air intake dampers will be controlled by an outside thermostat which will be reset by a humidistat. Thus the dampers will be at their maximum opening when the outside wet bulb is lower than that desired inside and at their minimum setting when the outside wet bulb rises above the inside; the change at which this will take place is approximately 67 F wet bulb.

No control over inside relative humidity will be exercised except that which results from the operation of the bypass damper and the adjustment of the chilled water thermostat. This combination will not maintain constant relative humidity, but will confine the variation within the limits of the comfort zone as shown by recent reports of the ASHVE research laboratory.

At times of light load, return water from the cooling coils will be bypassed around the storage tank in order to maintain a constant water temperature entering the dehumidification coil. The thermostat which controls this operation may be adjusted in the field to get optimum conditions.

The zoning of the duct system for the office has already been mentioned. These zone dampers are controlled from thermostats situated in the respective return air ducts.

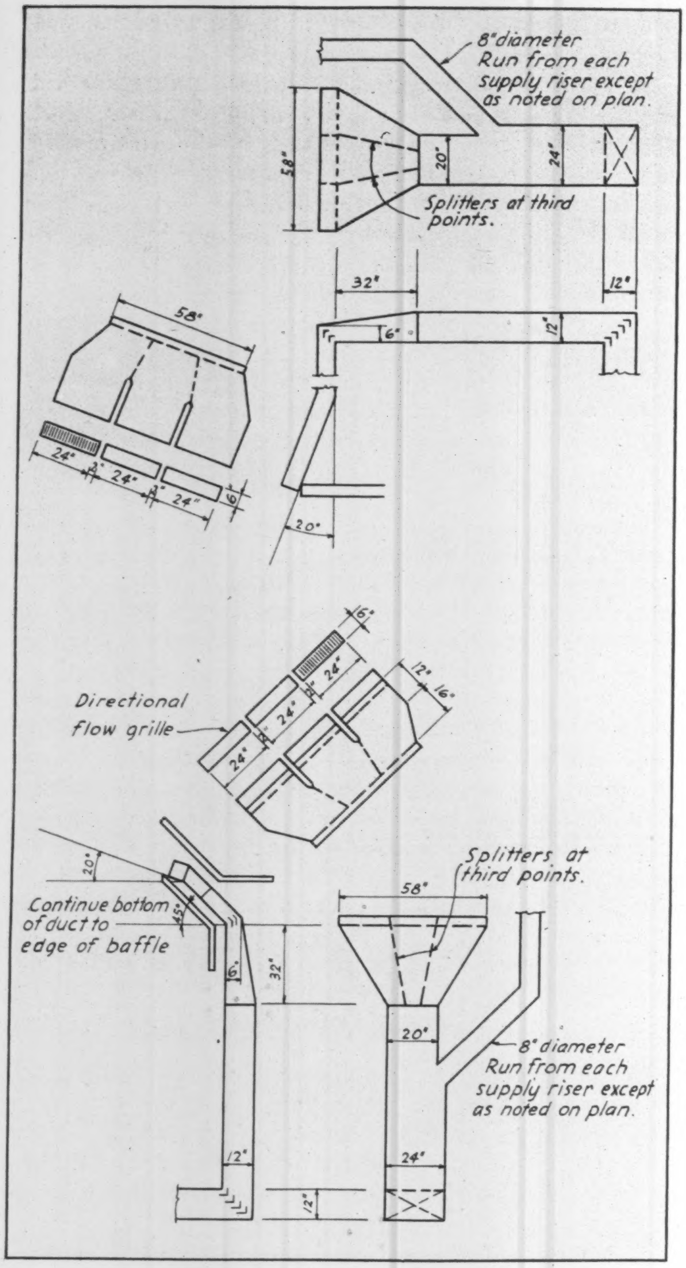
The Air Distribution

All duct work except that in machine rooms and shops is concealed, and both the architect and the structural engineer gave splendid coöperation in making slight changes in architectural design or in altering the location or style of framing in order to accommodate the duct work.

Space restrictions dictated many sharp angled bends, and to maintain good flow conditions splitters were specified at many points. Before approval was given for grille sizes and locations, architectural details of all important interiors were made. Because of this careful study, the duct work was installed substantially as was shown on the drawings and with minimum interference from other trades.

Directional flow grilles are used for all wall outlets. Wherever possible these grilles were selected for high aspect ratio and relatively high grille velocities in order that good secondary air circulation within the room will be created. This same type of grille is specified for ceiling supply in Gallery F-1, architecturally the most important room in the building. These grilles were carefully worked into the architectural design and lighting plan, and because of the great height of the room and the method of lighting, the grilles are scarcely noticeable. Return grilles in the galleries and lecture room are of ornamental design.

The nature of the planetarium chamber creates an individual problem. The occupants will be seated in the


8" diameter Run from each supply riser except as noted on plan.
58"
20"
24"
Splitters at third points.
32"
12"
6"
58"
24"
2"
24"
24"
6"
20°
6"
24"
12"
16"
24"
24"
Directional flow grille
20°
Continue bottom of duct to edge of baffle
45°
6"
32"
Splitters at third points.
58"
20"
8" diameter Run from each supply riser except as noted on plan.
12"
24"
12"

Details of duct work for the planetarium chamber

four quadrants, facing toward the center. All air movement in the occupied zone should preferably be from the center toward the walls. The ceiling of this room is a hemisphere of thin perforated steel painted white, which serves as a screen for the projection of "stars and planets" by the planetarium instrument. Naturally there could be nothing built into the dome which would destroy this surface. Below the spring line of the dome are several baffles which are set at 45 deg to the vertical and extend around the periphery of the room; their function is to conceal from the audience the image of a stray ray of light from the instrument so that there will be no "stars" visible below the horizon.

The supply ducts for this room were designed in basically the same manner as those successfully operating in both the Fels and Hayden planetaria. Several refinements were added such as the final bend in the nozzle, splitters, and directional flow grilles (see details). The grilles, selected from data furnished by the manufacturer, are intended to give more control to the trajectory which will reach just beyond the inner circle of seats. Return grilles are placed in the wall approximately below the supply. Thus a movement of air toward the faces of the spectators should take place in all parts of the occupied zone.

Clearances for the instrument elevator and the movable floor section made complex duct work necessary in the space under the floor of the planetarium chamber. The planetarium instrument will be mounted on an elevator deck and will be concealed within a pit while the audience assembles. After the lecture has started and the house lights have been turned off, the section of movable floor will be lowered and rolled out of the way, following which the instrument will be raised into position and the demonstration will begin.

All ducts and fan housings through which chilled air is handled are covered with 1½ in. corkboard. All joints were sealed with hot asphalt and over finished ceilings two brush coats of hot asphalt were applied to the exterior surface of the insulation. These precautions were taken to prevent condensation from forming on duct surfaces. Asbestos air cell covering was used on supply ducts for those systems which have no cooling coils.

Preventing Condensation on Dome

As mentioned before, the inner dome or ceiling of the planetarium chamber is made of perforated stainless steel sheets. These holes (fifteen $\frac{3}{32}$ in. diameter holes per square inch) allow sound waves to pass through the dome rather than to be reflected back to the audience. The dome is painted white so that it will give the proper light reflection. Because repainting of the dome will be expensive, it is important to keep its surface clean as long as possible. Should condensation form on the inner surface of the outer dome and then fall to the inner dome, streaking would soon occur. To guard against this, 2 in. of rigid board insulation was placed over the masonry arch forming the outer dome, and small branch ducts from the main supply risers were run up above the inner dome. In winter, the insulation will keep the inside surface temperature above the inside dew point, and the branch ducts will provide for air change between the two domes, the space being vented through the perforations in the inner dome. These precautions are also necessary to keep moisture out of the sound absorbing material which was applied to the inside masonry surfaces of the outer dome.

Predict Air-Borne Diseases?

It seems possible that there are certain diseases, including certain types of colds, possibly some forms of pneumonia and influenza, which are indigenous in certain localities and may be transported to other localities with air masses therefrom. It is not an idle dream that with further development of air mass analysis, along with medical climatology, predictions of the incidence of such diseases may become possible, so that persons subject thereto may, in effect, "hole themselves in" until the danger of infection has passed.—ROBERT E. HORTON, consulting engineer, in his presidential address before the American Meteorological Society.

Heat Transfer and Viscosity Effects in Ammonia Shell and Tube Brine Coolers

By Richard J. Panlener*

IT is the purpose here to review some of the data and tests on heat transfer in horizontal shell and tube coolers used for cooling calcium chloride brine. To present a simple and direct approach to the problem, only flooded evaporators will be considered.

The variable factors involved in the practical consideration of the changing values of heat transfer may be listed as (1) evaporating temperature, (2) initial and final brine temperature, (3) logarithmic mean temperature difference, (4) brine concentration, (5) brine specific heat, (6) brine velocity through the tubes, (7) number of brine passes, (8) size of the tubes, (9) type of surface, (10) arrangement of the surface, (11) refrigerant connections, (12) boiling point depression, (13) average brine viscosity, and (14) swirl strips.

Evaporating Temperature

The lowest evaporating temperature determines the brine concentration necessary for a particular application. It should be remembered that the concentration must be such that the brine will not freeze in the tubes. For this reason a margin must exist between the freezing point of the brine and the lowest evaporating temperature; this margin must take into account the human element in plant operation as well as possible load variations. Values of average brine temperature, lowest ammonia evaporating temperature and freezing temperature of still brine are shown in Fig. 1, which is a plot of values from the ASRE Refrigerating Data Book. (6)† These brine concentrations in reality have even a greater margin since moving brine freezes several degrees below the crystal forming temperature in still brine.

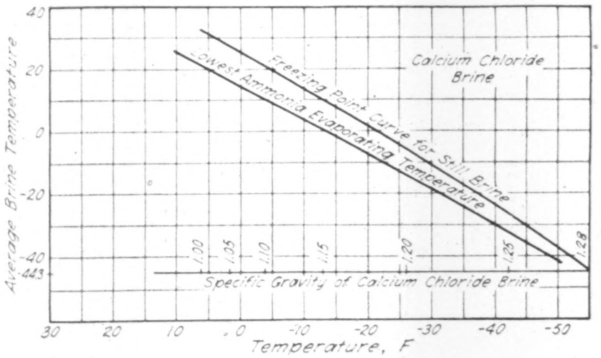


Fig. 1—The relationship for calcium chloride between average brine temperature, ammonia evaporating temperature and the brine freezing point temperature for various brine concentrations

Initial and Final Brine Temperature

The initial and final brine temperatures are necessary in determining the average brine viscosity and average brine specific heat. The rapid change in brine viscosity with small changes in temperature is shown in Fig. 2. These values are taken from the work by Stakelbeck under the direction of Plank and translated and converted by Kaufmann (*1*). In order to facilitate interpolation and the use of the Fahrenheit scale, the values have been plotted as shown. The variation of specific heat with working brine temperatures and concentrations is shown in Fig. 3. Although the variation of specific heat for a given concentration with change in temperature is small and may be neglected for practical purposes, nevertheless the great difference with varying concentrations readily indicates the necessity of accurately determining the correct brine density.

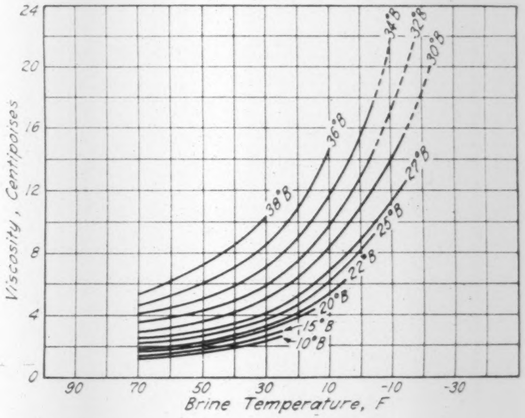


Fig. 2—Variation of viscosity in centipoises for changes in temperature and concentration for calcium chloride brine

Logarithmic Mean Temperature Difference

The effect of logarithmic mean temperature difference, MTD, on the heat transfer in horizontal shell and tube brine coolers is excellently reported by Consley (*2*) and

A thorough analysis of the factors influencing the overall heat transfer and friction values in horizontal multipass flooded ammonia brine coolers is presented by the author. After discussing the effects of the individual variables, an empirical heat transfer formula and accompanying curve give a simple and rapid method of selecting the heat transfer coefficients. A description of the determination of friction values by Reynolds numbers and an accompanying test curve to further establish its accuracy are also included. . . . The data are of interest to engineers concerned with refrigeration piping, and in connection with brine spray equipment for low temperature air conditioning

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*Vilter Mfg. Co.
†See bibliography.
Part 1.

is shown in Fig. 4. With 10 F brine, 1.28 specific gravity in 1¼ in. OD tubes 16 ft long and a brine velocity of 200 fpm he reports 70 Btu per sq ft per hr per F with a 4.5 deg MTD and 100 Btu per sq ft per hr per F at 12 deg MTD. The effect of MTD has long been recognized as an important item in flooded coolers. The rapid increase and then the falling off of the heat transfer coefficient with progressively increasing values of MTD indicate that this effect is on the refrigerant side of the tube. At a low MTD there is slow ebullition of the refrigerant accompanied by a rather heavy and slowly disturbed ammonia film on the tubes. As the MTD increases, the boiling becomes more vigorous, forming mass convection currents of the liquid refrigerant; the refrigerant actively flows over the banks of the tubes, rapidly washing away the gas bubbles and reducing the ammonia film. This increased movement of the refrigerant over the tubes, due to the MTD, increases the heat transfer on the refrigerant side just as the increased velocity of the brine through the tubes increases the heat transfer on the brine side. However, as the MTD continues to increase, a falling off of the heat transfer occurs due to the evaporation around the tubes taking place so rapidly that the ammonia gas forms a thin insulating layer. These conditions are of no practical significance, though, since this decrease does not occur until a cooler is operated under conditions which would be commercially uneconomical.

Brine Concentration and Specific Heat

The necessity of accurately determining the correct brine concentration both as to its effect upon the viscosity, Fig. 2, and as to its effect upon the specific heat, Fig. 3, has already been mentioned. Although the viscosity is the more widely varying figure, nevertheless the correct specific heat is necessary for the proper heat balance of the brine cooler. The brine concentration and temperature is obviously a determining factor in the internal thermal conductivity which is one of the fundamental pieces of information lacking for the complete and thorough dimensional analysis of brine cooler heat transfer problems. The few values listed in reference works are for conditions under which refrigeration equipment would not operate. The ASRE data book (*6*) lists the thermal conductivity of calcium chloride brine at 90 F. The conductivity of water varies 30 per cent from 32 to 212 F. It would also be interesting to know how the conductivity for brine varies, especially at low temperatures.

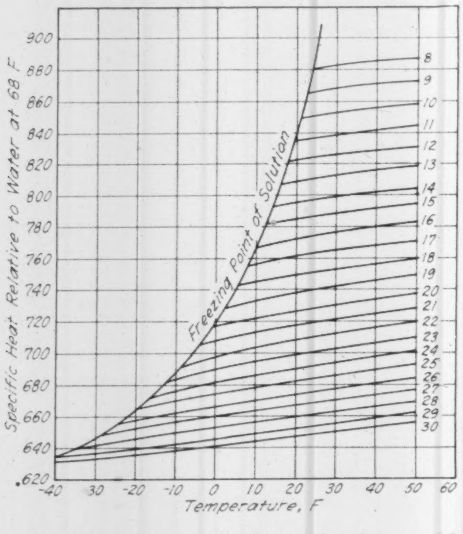

Fig. 3—Variation of specific heat of calcium chloride brines with changes in temperature and concentration

Brine Velocity

The effect of brine velocity through the tubes has long been recognized, although there has been little agreement as to its true effect since the original investigators did not take into account the other determining variables. For that reason it has been impossible to set up a correct overall heat transfer coefficient dependent solely upon brine velocity. Inasmuch as the variation of heat transfer due to velocity must take fluid flow into account, the actual influence of velocity will be considered under the discussion of viscosity.

Number of Brine Passes

The brine tests which were listed by Consley (*2*) were made with four, five and eight pass coolers. Other tests which have been analyzed were run on three, six, five and 10 pass coolers. Since there has been slight variation in heat transfer coefficients obtained in these different tests, questions have been raised as to whether or not the number of passes is a determining variable. It may be that these differences existed because of accumulative errors in test readings. However, it has been argued that if the number of passes has no appreciable effect upon the heat transfer coefficients, then the values obtained for horizontal multipass brine coolers should also be applicable to the single pass horizontal brine cooler, since this is nothing more than the lower limiting value of the number of passes. It will only be possible to settle this question after a complete analysis has been made of all the possible variables in the horizontal multipass coolers. If at that time the number of passes is not considered as a variable, then the heat transfer coefficients for the multipass coolers should apply also to the single pass coolers.

Effect of Tube Size

As shown by the plots in Consley's paper (*2*) and as stated by McAdams (*3*) the heat transfer varies inversely as the outside diameter of the tube. This increase again is due to the greater agitation of the liquid film. This directly follows from the permissible arrangement of the tubes according to their outside diameter. From a practical design and manufacturing point of view it is possible to arrange more small outside diameter tubes in a tube sheet of a given size. For example, in a 28 in. external shell diameter in the tests correlated by Consley (*2*) there were one hundred and forty-four 1¼ in. tubes in the one case as compared to fifty-four 2 in. tubes in the other. For a 1 in. thick tube sheet the RMA (*4*) recommends a similar procedure, allowing a ½ in. minimum ligament for 2 in. OD tubes and a ⅜ in. minimum ligament for 1¼ in. OD tubes.

This variation in tube arrangement changes the net area available for refrigerant circulation around the tubes.

The smaller tubes also displace more refrigerant. This leaves a smaller quantity of liquid refrigerant to be circulated by convection currents, a condition which is brought about by the MTD. However, it must be remembered that the closer arrangement permissible with smaller tubes undoubtedly brings about a greater resistance to the liquid refrigerant circulation. A combination of a more rapid circulation because of the smaller net available area between the tubes and a greater number of tubes results in a more complete bathing of the external tube walls by the liquid refrigerant. Under these conditions the heat transfer coefficient on the refrigerant side is increased because of the more rapid removal of the evaporated refrigerant and the decreased refrigerant film resistance.

From the values taken from Fig. 4, the plot by Consley (*2*) for a constant condition of 200 fpm brine velocity and an MTD of 9.5 F with 1.28 specific gravity brine at 60 F, the variation in heat transfer is slightly less than the inverse ratio of the tube diameters to the 0.2 power. This checks accurately with the work by Eagle and Ferguson on heated water flowing in turbulent motion in the horizontal brass pipes having diameters of 0.5, 0.75, 1.0 and 1.5 in., which showed that for a given water velocity, the coefficient of heat transfer varied inversely as the 0.2 power of the diameter (*3*). The following table from the data book (*6*) is set up on the same basis:

Effect of Tube Diameter upon Forced Convection Coefficients

Diameter, in.	0.1	0.25	0.5	0.75	1.0	1.5	2.0	4.0	6.0
Flow inside tubes	1.59	1.32	1.15	1.06	1.00	0.92	0.87	0.76	0.66

To obtain the coefficient for any tube size multiply the heat transfer coefficient by the inverse ratio of the above values.

Type of Surface

The condition of the surface is a vital factor in the variation of heat transfer. Just as smooth internal surfaces lead to lower fluid pressure drops and a smooth external surface to higher condensing coefficients, so do roughened external surfaces promote higher rates of evaporation. This factor has been reviewed by King and Knaus (*5*) and by McAdams (*3*) in his report on the tests of Heidrich and Jakob. For high heat transfer coefficients from the surface to the boiling liquid, the metal surface should be clean and rough. Oxidation and scale will retard heat transfer, thus losing the beneficial effect of a clean, rough surface.

Arrangement of Surface

As previously stated in discussing the size of the tubes, a definite change in heat transfer occurs with different tube sizes. Another factor in the arrangement of the surface which is known to produce a marked change in the brine film is the length of the tube. In turbulent flow through the tube, the brine forms three recognized zones—the film, the buffer layer, and the turbulent core. The brine film adheres to the metallic surface of the tube and does not move appreciably as the rest of the brine passes through the tube. Heat being transferred from the body of the brine to the refrigerant must pass through this film by conduction. The buffer layer or zone is a slowly moving region which mixes slightly with the film and the turbulent core and through which heat passes both by convection and conduction. The turbulent core represents by far the greater part of the moving mass of brine and it is this zone, for the most part, that is available for use.

Fluid flowing through a tube under constant conditions has a tendency to approach an even flow in which there is a constant turbulence, a constant mixing with the buffer layer, and a constant brine film adhering to the tube wall. However, in a multipass cooler the brine flows the length of the pass, is directly reversed in its direction of flow, and returns through the next pass. This interruption to the fluid flow causes additional turbulence both upstream and downstream from the point of interruption. Hence, passes cause a greater mixing of the turbulent core, a greater agitation of the buffer layer and a disturbance in the film. The effect of this additional upstream and downstream agitation remains constant regardless of the length of the cooler so that there is a possibility that the number of passes in the arrangement of the surface would vary the amount of heat transferred. Again the limiting value of surface arrangement would be the single pass horizontal brine coolers.

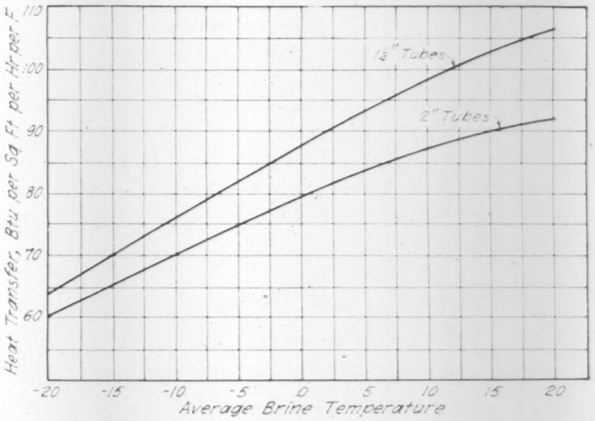

Fig. 4—Heat transfer in flooded brine coolers as function of brine temperature with velocity of 200 fpm and MTD of 9.5 deg

Refrigerant Connections

The refrigerant connections on a brine cooler are identical in type and effect to those on any flooded evaporator. The liquid inlet must be so placed that the flash gas does not rob the cooler of any of its effective evaporating surface and at the same time does not permit the surface of the liquid to be so disturbed as to cause liquid slugs to be carried along with the suction gas. The suction connections should be sized and placed so that the evaporated refrigerant is readily removed at a low velocity, so that there is no tendency to carry liquid refrigerant along with the gas, and so that the pressure is not allowed to build up in the cooler. In a long cooler with only one small suction connection in the center, the evaporating pressure at the center of the cooler will be slightly less than the pressure at the two extreme ends. This increase in pressure caused by the gas binding of the extreme ends gives a false indication of the effective evaporating surface and hence would not permit an accurate analysis of the heat transfer coefficients. Frequent tests on evaporators have indicated that different types of liquid and suction connections materially affect the evaporator capacity and hence the heat transfer coefficient.

[*To be concluded*]

Controlling Quality of Pipe Welds

By **R. W. Breckenridge***

WITH the growth of welding of piping and pressure vessels has developed the need for ascertaining the quality of welded joints. One of the non-destructive methods evolved that is being applied to arc welded joints is that of the arcronograph.

During the summer of 1938 the writer operated one of these instruments at the Iowa Power and Light Co. plant at Des Moines. A new addition was being constructed at the time which consisted of a turbo-generator unit driven by steam supplied by a boiler fired with pulverized coal. The steam pressure is 1290 psi and the temperature 925 F at the throttle. The main line from the boiler to the turbine is 10 in. molybdenum steel pipe 1⅛ in. thick. The boiler feed line was designed to withstand 1900 psi. The procedures in welding these lines followed quite closely those for the remodeling job recently carried out at the Conners Creek station at Detroit. Briefly, they consisted of preheating the joints to 425 F with either wrap around resistance coils or aluminum induction heaters. The heat was maintained during the welding. When the weld was completed, the joint and adjoining pipe were heated to 1200 F to relieve possible stresses due to unequal heating from the arc.

The Welding Process

While the welding was proceeding, records were taken with the arcronograph. The action of this instrument is based on the fluctuations in voltage that occur in the circuit through the welder's arc. A study of the movement of metal at that point shows that the end of the rod, on heating up, becomes fluid. This fluid, due to surface tension, tends to form a sphere; since it is attached to the end of the rod the form is really that of a pear. This pear shaped drop apparently takes on a spinning and elongating motion. Finally it extends out so far that the spherical end touches the puddle. A short then occurs in the circuit, but for only an instant. The surfaces of the puddle and of the drop break. The neck whereby the drop has been attached to the electrode now breaks. The drop enters the puddle and the arc is again set up between the puddle and the end of the electrode. Thus the voltage in the circuit through the arc continually varies. While the drop is forming the arc is in action heating and fusing the base metal, as well as the end of the electrode. The ratio that exists between the time required for each drop to form and the base metal to melt, and the time during which the circuit is shorted in depositing each drop, is the basis on which the performance is determined and consequently the basis on which the quality of the weld is determined.

The forming and depositing of the drops take place so rapidly that the instruments commonly used for indicating changing voltages cannot keep up with the rapid actions. In the arcronograph a vacuum tube is used, since it has no inertia. The power to the tube is usually supplied from an a-c circuit in which the current is rectified. The fluctuations are recorded on a strip of paper by means of a balanced fountain pen feeding the ink through a capillary tube, the intake end of which is free to move in the ink supply reservoir. When the voltage rises the pen moves to the right and when it drops the pen moves to the left. A small synchronous motor moves the strip of paper under the pen at a uniform rate. When the welder stops work the recording mechanism continues for a very short time and then, to save chart paper, shuts off automatically.

It is not difficult to place the instrument near enough to the work so that the arcronograph operator can observe the welder. This was found quite desirable in that the arcronograph operator could record with symbols or abbreviated notes on the margin of the record strip the bead which was being applied to the joint and the position on the circumference of the pipe where the welding was being done. In that way it was possible to locate definitely the part of a welded joint which each part of

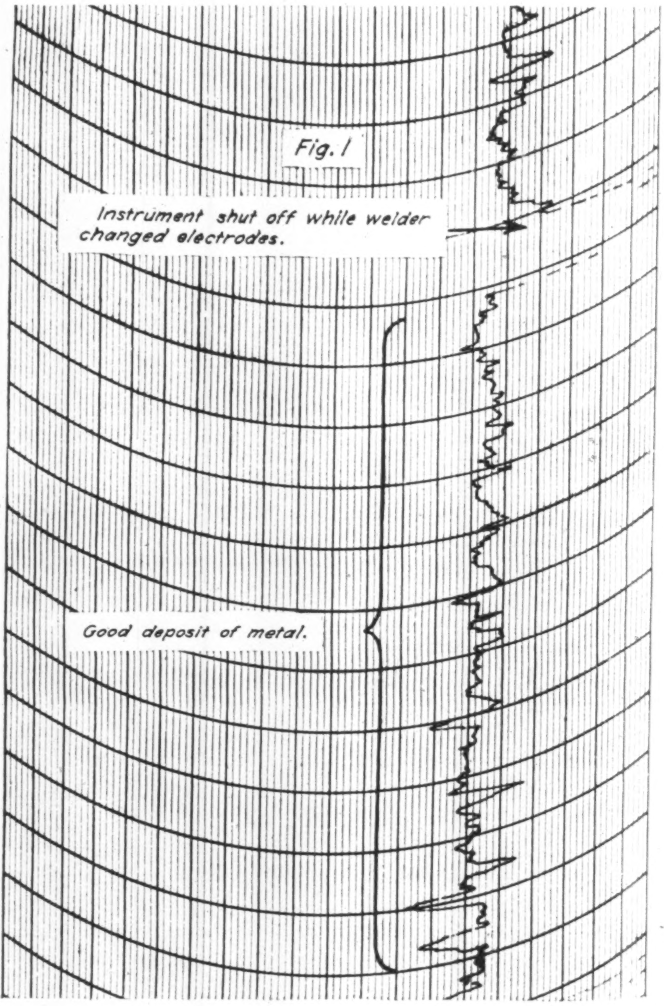
Fig. 1

Instrument shut off while welder changed electrodes.

Good deposit of metal.

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*Department of Mechanical Engineering, Iowa State College.

the arcronogram represented. In addition to this information, the joint being welded was recorded.

Work on the alloy steel pipe carrying the two highest pressures was done by a welder who had been welding since he was about 16 years old. He worked with his face unusually close to the arc in order to observe carefully the action of the metal as it was being deposited. For the arcronograph operator to see the same thing it was necessary for him to get equally close. However, he did not need to remain in that position any longer than was sufficient to learn what was going on and why.

Last summer the author operated an arcronograph in connection with the welding of high pressure piping at the Des Moines plant of the Iowa Power and Light Co. He experimented in coördination of the patterns that appear on the charts with the techniques of a skilled welder working on field welds. . . . Although it is sometimes thought that a steady line on these charts is the only pattern that is desirable, the studies indicated this is not always the case

Interpretation of the Arcronogram

If the welder is working down-hand on a piece of pipe that is in the best position possible in so far as his comfort and convenience is concerned; if he is using the same kind of electrode as is to be used on the job; if the material and size of the pipe being welded is representative of that to be used on the job; if his welding machine is adjusted to the best possible conditions; and if the joint is prepared as the other joints will be prepared, then he can produce an arcronogram with an ideal pattern. This will consist of a line containing small but uniform waves and the axis of the line will run vertically on the chart, as in Fig. 1. If the arc is elongated, the axis of the line will move to the right. When the arc is so long that it continually breaks, the line will consist of zig-zag marks touching the right edge of the chart and the weld will be porous and badly burned. If the arc is shortened, the axis of the line will move to the left and less of the base metal will be melted. If the arc is shortened too much, the electrode will stick. This means a short circuit and a wide swing to the left on the chart.

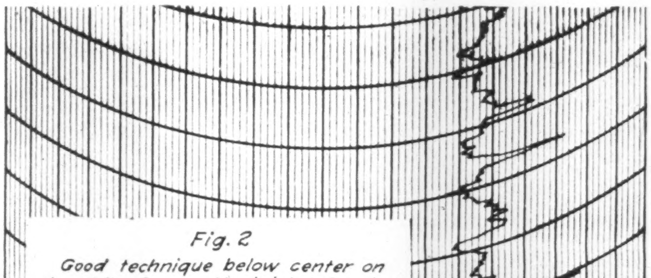


Fig. 2

Good technique below center on the side of a vertical joint. Regular swings to the right indicate slight elongation of arc while "whipping" ahead along the sides of the notch to heat base metal and momentarily prevent deposit of metal. Thus "sliding" of the metal is avoided and good penetration is assured.

If all welding could be done down-hand and with comfortable working conditions, arcronographic checking of welds would be a comparatively easy procedure. But field welds must be made in fixed positions of the pipe which require that the welder work in restricted and uncomfortable positions. Then it is necessary to observe carefully what welding techniques are used to maintain the proper penetration ratio and to avoid the sliding of the metal that is being applied. After these techniques have been studied and the ones approved that result in high quality welds, then it is necessary to identify these techniques in the patterns appearing on the arcronograms. A knowledge of both desirable and undesirable techniques is necessary for both the arcronograph operator and for the inspector. A record on the margin of the chart is also necessary to indicate what part of the joint is being welded. Otherwise it is not possible to determine what technique is the proper one for the position.

Welding a Vertical Joint

Fig. 2 illustrates how one of the welders manipulated his electrode on a vertical joint. At a point about a third of the way up from the bottom, the most difficulty is encountered. There the metal being deposited will not hang in position and neither will it build up in shelf fashion. As the welder weaves his electrode back and forth from one side of the notch to the other he alternates these passes with short whipping motions along the side of the notch and ahead of the deposit. At the same time he elongates the arc slightly to momentarily avoid depositing metal. This short time interval also permits the metal already deposited to solidify. In this manner a good penetration ratio is maintained and at the same time the metal does not slide back. The chart vibrations, which are wider than usual, might be mistaken for unsteady handling of the electrode holder.

Another example is in finishing off at the top of the joint. The fluid metal in the puddle tends to level off rather than build up in a well rounded bead. By momentarily withdrawing the electrode, the fluid metal will solidify sufficiently to build up in the manner desired. This maneuver produces an arcronogram consisting of a series of rather wide swings.

When the welder was welding under these conditions, other workmen would often be around watching the

[*Concluded on page* 360]

Blushing on Lacquered Pencil Parts Overcome by Gas Fired Dehumidifier

By **Henry Hartmann***

ANOTHER adaptation of summer air conditioning to solving industrial production problems is reported at Eberhard Faber Pencil Co., Brooklyn, N. Y. This nationally-known manufacturer of pencils and erasers has found it expedient to call upon silica gel dehumidification equipment to preclude shut-downs of the lacquer room on high humidity days—not infrequent in Brooklyn during the summer months.

On numerous occasions in recent years the Eberhard Faber finishing department has had trouble with "blushing" or the development of "orange peel finish" on light lacquered parts—sufficiently so to make it impossible to carry on until the interfering weather wave passed. This meant intermittent operation of the lacquer room, reacting adversely upon a normally smooth and efficient production plan. It affected workers' time schedules, operating expenses of the department, percentage rejects, and storage and shipping activities.

An analysis of the problem revealed that the lacquer, in drying, caused a sufficient cooling effect upon small thin-wall metal parts (such as pen and pencil fitments) as well as upon parts of low heat conductivity (such as the bodies of wooden pen and pencil shafts) to bring the temperature at the lacquered surface down below the dew point of the atmosphere in the room on excessively humid days. As a result, water was condensed out on the drying surface, and it was this moisture which caused the trouble. On heavier metal parts the effect was not noticed, apparently because the heat conductivity and heat content of the part were sufficient to counteract the cooling effect as fast as the drying process developed it. But extremely thin pencil casings and wooden pen shafts (which could not rapidly enough "dissipate the cold" developed by the evaporating volatiles in the lacquer) presented a problem.

The answer obviously lay in reducing the moisture content of the atmosphere in the lacquer room so that the dew point would be maintained safely below the lowest surface temperatures developed on the work in the lacquer booths. It was found that different critical dew points existed for different lacquers and types of work, the lowest such temperature being about 62 F.

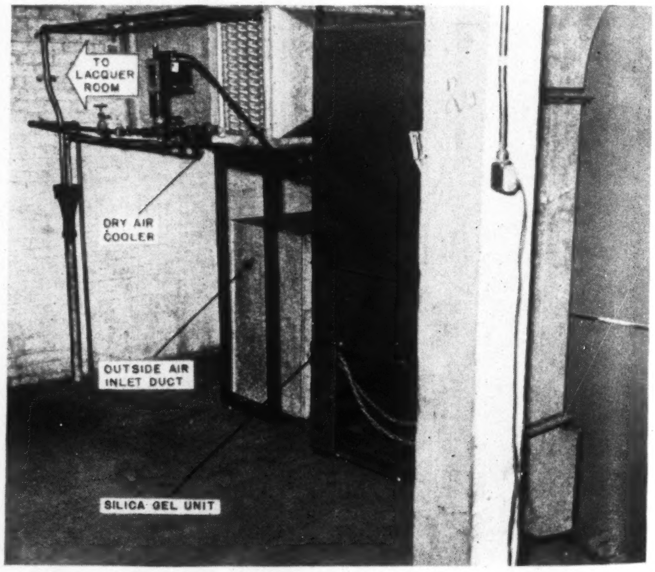
To accomplish the desired job—to remove the moisture from the lacquer room air and thus sufficiently lower its dew point—a gas fired silica gel dehumidifier was installed. The unit is capable of delivering 2700 cfm of dried air, and is equipped with an aftercooler of standard design connected to the city water supply. From the aftercooler, the dried and cooled air is conducted through the brick end wall of the lacquer room and discharged from several side registers in the single tapering duct which runs centrally about three-quarters of the length of the lacquer room just a foot or so below the ceiling.

Although the silica gel unit delivers 2700 cfm of dried air into the lacquer room, the exhaust blowers on the several lacquering benches remove air from the room at a rate of 5000 cfm. Thus 2300 cfm of humid outside air filters in through doors, windows and walls.

The humidistat, situated 5 ft from the floor in the center of the lacquer room, is set to keep the mixed room air at 50 per cent relative humidity. Of course, the air flowing from the silica gel unit must be dryer than this final condition. In this manner the dehumidifier is kept operating at its most efficient level and is required to carry only about half the air needed for circulation through the 75 x 25 x 10 ft lacquer department.

Temperature is no special problem. The rate of flow of the approximately 60 F city water through the cooling coils between the dehumidifier and the dried air duct is generally regulated to keep the temperature of the dried air near the temperature of the outside air with which it mixes in the lacquer room. Should the day be unduly hot, it is very easy to keep the lacquer room temperature between 80 and 85 F—a comfortable condition with the humidity as low as it must be to prevent blushing.

As for results, Eberhard Faber's lacquer foreman says, "Since making the installation, we have never had to shut down lacquering operations due to bad weather, and my department functions much more smoothly." He also mentions that comfort conditions have been improved, and that it is possible to use less expensive lacquers for the same results. Undoubtedly, drying times are reduced, although this is not a factor.



Equipment which supplies dried air to Eberhard Faber's finishing department, solving a production problem

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*The Brooklyn Union Gas Co.

The Psychrometric Chart

Its Application and Theory

By William Goodman*

ALTHOUGH psychrometric charts have been available for many years, they have seldom been used for any purpose other than the elementary one of showing the relationships between the dry bulb, wet bulb, and dew point temperatures, and the relative humidity. In addition to these elementary uses, the chart provides a simple and enlightening means of analyzing many complex air conditioning problems. Some of these problems were discussed in a previous article.[1] In the present article the methods of using the chart for analyzing other types of problems are discussed. More important still, the general theory of the chart is described in detail. With the background of this general theory, any type of problem can be attacked.

Nearly all of the problems presented here can be solved analytically without the use of the chart. However, a graphical analysis on the chart not only eliminates considerable tedious arithmetical work, but also has the merit of providing a vivid and illuminating picture of the air conditioning process. Such a picture frequently suggests the treatment to which the air must be subjected in order to achieve a desired final result.

The new psychrometric charts that are presented here greatly facilitate the solution of most problems and lead to a clearer understanding of the fundamentals involved than can otherwise be obtained.

The Chart in General

The conventional charts heretofore available have usually been plotted with dry bulb temperature as the abscissa and absolute humidity† (moisture content) as the ordinate. Chart A is plotted with enthalpy (total heat) as the abscissa and absolute humidity as the ordinate. Although the difference between the ordinates of the new and old charts may seem, offhand, to be of little account, nevertheless, as will be shown later, this difference marks a fundamental and really important change.

Mollier[2,3] (of Mollier steam diagram fame) was the first to plot a chart with these coördinates and to show its value. Grubenmann[4] and Hirsch[5] have also extensively developed the uses for this type of chart. Much—though not all—of the material in this article is based on their work.

A chart potted with enthalpy and absolute humidity as the coördinates facilitates the analyses of air conditioning problems by means of the "energy equation" method, which has so simplified analysis of all thermal processes. The energy equation method, despite its formidable name, is really simple and has eliminated a host of difficulties that were inherent in older methods of analysis. The energy equation is discussed in more detail later.

The chart that will be used in this discussion is Chart A; as stated before, the abscissa is the enthalpy of the air-vapor mixture, and the ordinate is the absolute humidity. Instead of being vertical the enthalpy lines are inclined at an angle for reasons that are discussed later. This not only makes the chart more readable, but also has the important advantage that a chart drawn in this way will have the familiar appearance of the conventional charts that have been used heretofore.

The geometry of the chart is discussed in detail later. In this section only those few points are touched upon that should be understood in order to use it.

Besides Chart A, additional ones will be published in later issues and will cover the low temperature range from —20 to +40 deg and the high temperature range from 0 to 450 deg.

The method of computing the data on which the charts presented here are based was discussed in detail in an earlier article[6] in which a set of new psychrometric tables was presented.

Chart A shows several saturation curves for various barometric pressures. When working on a particular air conditioning problem, use the saturation curve corresponding to the one barometric pressure under which the air conditioning process is assumed to take place—all of

In addition to the elementary uses of the psychrometric chart—such as showing the relationships between dry bulb, wet bulb, and dew point temperatures, and relative humidity—it provides a simple and enlightening means of analyzing many complex problems in comfort and process air conditioning, including drying. . . . New psychrometric charts covering the low, middle and high temperature ranges, with saturation curves for various barometric pressures, are presented here. The general theory of the psychrometric chart is discussed in detail, and the methods of solving problems by the use of charts are described. . . . These new charts facilitate solution of most problems and lead to clearer understanding of the fundamentals

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*The Trane Co. Member of Board of Consulting and Contributing Editors.

†This term is here used to denote pounds of moisture per pound of dry air in the mixture.

[1] New Uses for the Psychrometric Chart in Simplifying Air Conditioning Problems, HEATING, PIPING AND AIR CONDITIONING, February-May, 1936.

[2] R. Mollier, Ein Neues Diagramm für Dampfluftgemische, *Zeitschrift* VDI, September 8, 1923, Vol. 67, p. 869.

[3] R. Mollier, Das *ix*-Diagramm für Dampfluftgemische, *Zeitschrift* VDI, July 20, 1929, Vol. 73, p. 1009.

[4] M. Grubenmann, *Jx*-Tafeln Feuchter Luft, published by Julius Springer, Berlin, 1926.

[5] M. Hirsch, Die Trockentechnik, published by Julius Springer, Berlin, 1927.

Part 1.

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[6] New Tables of the Psychrometric Properties of Air-Vapor Mixtures, HEATING, PIPING AND AIR CONDITIONING, January-February, 1938.

the saturation curves for the remaining barometric pressures should be disregarded.

The lines of constant dry bulb temperature slope slightly from the vertical and also diverge from each other; the slope of each line of constant dry bulb temperature is different. As is shown later, the horizontal distances on the chart are proportional to the sensible heat of the dry air and the superheated vapor mixed with it. If the sensible heat of the vapor were ignored, all of the lines of constant dry bulb temperature would be vertical and parallel to each other.

No lines of constant wet bulb temperature are shown on Chart A. The location of the wet bulb lines differs for various barometric pressures. Lines of constant wet bulb temperature cannot be drawn on a chart like A which is to be used for various barometric pressures. However, the lines of constant wet bulb temperature are all straight lines on a chart which is plotted with enthalpy and absolute humidity as the coördinates. Consequently, the few wet bulb lines that may be needed for any particular problem can be drawn quickly by means of either of two simple methods that are presented later.

Symbols

B_a = perfect gas constant for air, 53.34
B_v = perfect gas constant for water vapor, 85.76
c = humid specific heat of air-vapor mixture ($c = 0.24 + 0.45w$)
d = density of water vapor, lb per cu ft
d_s = density of saturated water vapor, lb per cu ft
G = weight of dry air, lb per min
G' = weight of water, lb per min
h = enthalpy of air-vapor mixture, Btu per lb of dry air in the mixture
h_f = enthalpy of moisture in liquid state, Btu per lb of water
h_g = enthalpy of moisture in vapor state, Btu per lb of vapor
h_o = enthalpy of moisture in any state, Btu per lb of moisture
L = actual length of a line on psychrometric chart, in.
P = total barometric pressure, in. of mercury
p = partial pressure of water vapor, in. of mercury
p_s = partial pressure of saturated water vapor, in. of mercury
Q = quantity of heat added to the air or removed from it, Btu per min
q = moisture ratio, Btu per lb of moisture evaporated into the air or condensed from it
q_D = moisture ratio for slope of a line of constant dry bulb temperature, Btu per lb of moisture
q_s = sensible heat ratio. See equations 6 and 8a of the text
r = latent heat of moisture
s_H = scale to which enthalpy lines are drawn on psychrometric chart, Btu per in. of scale length
s_M = scale to which absolute humidity lines are drawn on psychrometric chart, lb of moisture per in. of scale length
T = absolute temperature, deg Fahr
t = dry bulb temperature, deg Fahr
t' = wet bulb temperature, deg Fahr
v = specific volume of air-vapor mixture, cu ft per lb of dry air in the mixture
W_o = weight of moisture evaporated into the air or condensed from it, lb per min
w = absolute humidity of the air-vapor mixture, lb of moisture per lb of dry air in the mixture
w_s = absolute humidity of saturated air-vapor mixture, lb of moisture per lb of dry air in the mixture
θ = moisture ratio angle. See Table 1.
β = slope of enthalpy lines
ϕ_P = percentage humidity
ϕ_R = relative humidity

Subscript "1" refers to the initial state of the substance and subscript "2" refers to its final state.

Dew Point Temperature

The method of reading dew point temperatures on the psychrometric chart described here is the same as the method used on other conventional charts. This method, illustrated in Fig. 1, is based on the fact that the dew point and dry bulb temperatures of saturated air are equal to each other. The dew point temperature of air in the state represented by point *1* is to be found. Extend a horizontal line through point *1*. Assume that the barometric pressure is 32 in. The horizontal line through point *1* intersects the saturation curve for a barometric pressure of 32 in. at point *2*. The dry bulb temperature at point *2* is equal to the dew point temperature of the air whose state is represented by point *1*.

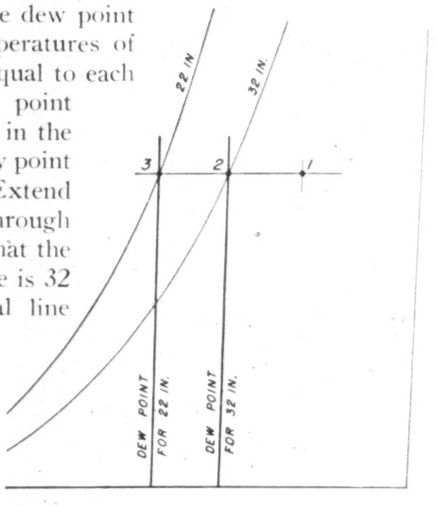


Fig. 1—Illustration showing method of using chart to find dew point temperatures of air at various barometric pressures

If, in the foregoing illustration, the barometric pressure had been 22 in. instead of 32 in., the horizontal line drawn through point *1* would be extended until it intersected the saturation curve at point *3*. For a barometric pressure of 22 in., the dry bulb temperature through point *3* is equal to the dew point temperature of air in the state represented by point *1*.

Moisture Ratio

A process in which air flows through a chamber where its enthalpy and absolute humidity are changed is illustrated in Fig. 2. In this process a *constant* quantity of heat is added to the air by the coil and a *constant* quantity of steam is sprayed into the air

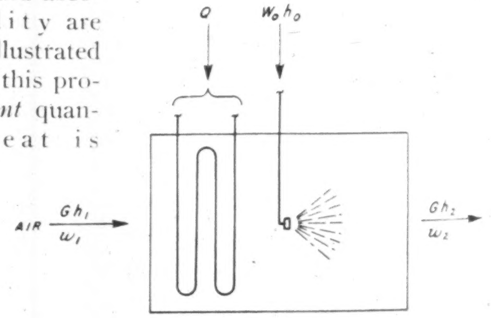


Fig. 2—Diagrammatic illustration of an air conditioning chamber in which a *constant* quantity of heat and steam are added to the air flowing through the chamber

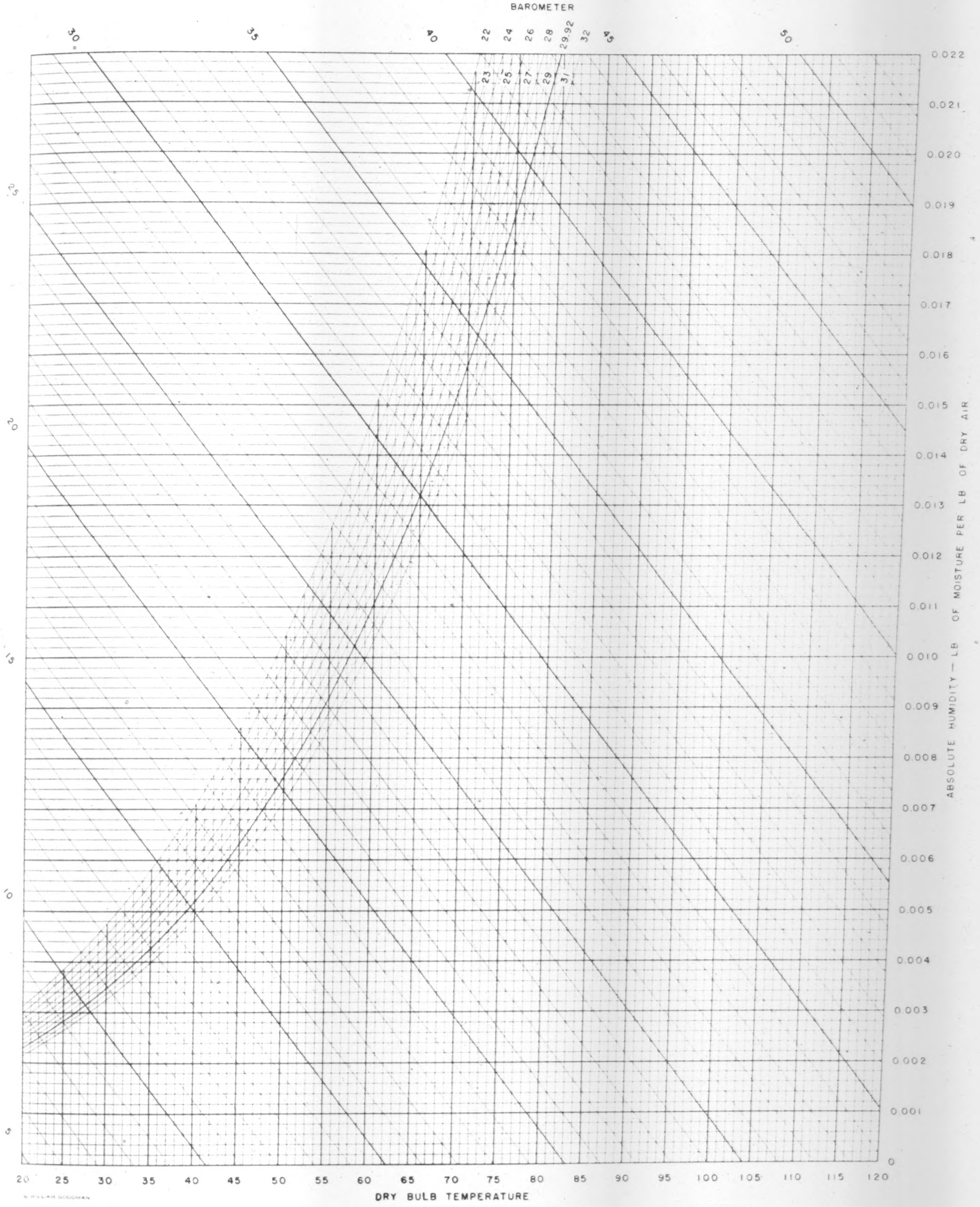


Chart A—Psychrometric chart for middle range of temperatures from 20 deg to 120 deg by the nozzle. The process of Fig. 2 could very well be used to represent a conditioned room where heat and water vapor are added to the air flowing through the room.

Inasmuch as heat can neither be created nor destroyed, all of the heat and moisture supplied to the chamber must be carried away by the air flowing out of it. This is true after the dry bulb and dew point temperatures of the leaving air have become steady—in other words, when steady conditions have been established inside the conditioning chamber.

After a steady condition has been established, the heat carried into the chamber by the entering air plus the heat added must be equal to the heat carried out of the chamber by the leaving air.

Writing a heat balance for the chamber,

$$Gh_1 + Q + W_oh_o = Gh_2$$

$$G(h_2 - h_1) = Q + W_oh_o \quad \ldots\ldots\ldots\ldots [1]$$

In the same way, all of the vapor entering the chamber must be carried away by the leaving air.

$$Gw_1 + W_o = Gw_2$$

$$G(w_2 - w_1) = W_o \quad \ldots\ldots\ldots\ldots [2]$$

Dividing [1] by [2],

$$\frac{h_2 - h_1}{w_2 - w_1} = \frac{Q}{W_o} + h_o \quad \ldots\ldots\ldots\ldots [3]$$

The quantity $[(h_2 - h_1) \div (w_2 - w_1)]$ will henceforth be called the *moisture ratio* and denoted by the symbol q. It represents the quantity of heat added to the air *per pound of moisture* added to the air. This quantity of heat that is added includes not only the heat needed—if any—to evaporate the moisture, but also the heat that raises the temperature of the air itself. Similarly, for a cooling process the *moisture ratio* represents the quantity of heat lost by the air *per pound of moisture* condensed from the air-vapor mixture. In this case the numerical value of the moisture ratio represents the latent heat of the condensed moisture plus the heat lost by the air as it cools. The case in which heat is added while moisture is removed, or vice versa, is discussed later.

Let

$$\frac{h_2 - h_1}{w_2 - w_1} = q \quad \ldots\ldots\ldots\ldots [4]$$

Hence,

$$\frac{Q}{W_o} + h_o = q \quad \ldots\ldots\ldots\ldots [5]$$

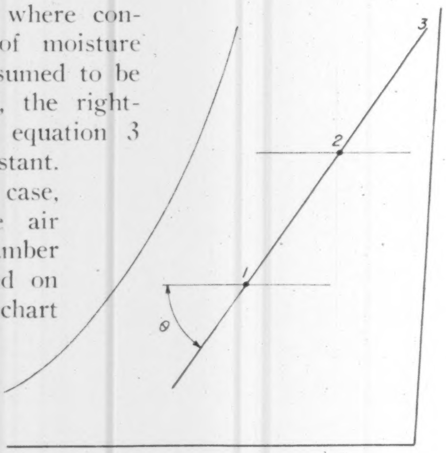


Fig. 3—Diagrammatic illustration of ratio line and ratio angle θ on the psychrometric chart

For the conditions illustrated in Fig. 2 where constant quantities of moisture and steam are assumed to be added to the air, the right-hand member of equation 3 must also be a constant. When this is the case, the state of the air *leaving* the chamber can be represented on the psychrometric chart by a series of points lying on a straight line as in Fig. 3. This is discussed further in Appendix 1. If point *1* represents the state of the air entering the chamber, the point representing the state of the air *leaving* the chamber must lie on the straight line *1-3*. Equation 3, and also equation 4, is the equation of a straight line on the psychrometric chart only if the *right-hand member is constant*. Such a straight line will henceforth be called the *ratio line*.

Air in the state represented by point *1* of Fig. 3 enters the chamber. As it flows through the chamber, heat and moisture are added, and the air emerges in the state represented by point *2*. The state of the air leaving the chamber is always represented by a point lying somewhere along the line *1-3* of Fig. 3.

The points on a ratio line do not—except for a few special cases that are discussed later—represent the state of the air as it flows through the conditioning equipment. These points represent only the possible states of the air *leaving* the chamber. In other words, if air leaves in the state represented by point *2*, the path of the points representing its state as it flows *through* the chamber may not be along the line *1-2*. The state of air may follow some roundabout path, but eventually the air leaves the chamber in a state that can be represented by a point on the ratio line. This is discussed in more detail later.

The *slope* of the ratio line depends only upon the numerical *value of the moisture ratio*. The formula giving the ratio angle in terms of the moisture ratio is presented later in a discussion of the geometry of the chart.

[*To be continued*]

Controlling Quality—

[*Concluded from page 355*]

record. The easy assumption for them to make was that a steady line on the chart indicated a steady hand and a line with rather wide swings in it indicated nervousness on the part of the welder. But he was of an independent and cheerful nature and did not stop to explain what the zig-zag lines indicated to one acquainted with voltages, heats, and welding positions.

Unfavorable features in the present use of the arcronograph appear to be that: (1) It does not record positively the presence of isolated defects; for instance, it is possible to build in an air pocket and yet avoid having it appear on the chart. (2) The very desirable marginal notes are a little difficult to make while the chart is in motion. (3) Technique patterns have not been worked out as extensively as might be desired, especially for welding in difficult positions.

The favorable characteristics possessed by the arcronograph as an instrument for checking the welding of pipe in the field appear to be that: (1) It records directly the varying voltage conditions, both good and bad, under which the weld metal is being deposited. (2) It gives indirectly a moving picture of the welder's movements in handling the electrodes. (3) It can be moved about easily and gotten into difficult positions. (4) Current required to operate the tube circuit is easily available. (5) The record is available the instant it is produced. (6) The cost of charts and current for operating the instrument is low. (7) The psychological effect on a welding operator of having a mechanical device continuously recording his performance is that he will probably put forth his best effort continuously.

United States Housing Authority Releases Information on Heating

THE following material is reprinted from a bulletin of the United States Housing Authority on the heating of low rent housing projects. The sections given here are the introductory paragraphs and Part 1 on economic analysis. The following parts on designing the heating system, preparing the contract documents, and fuel consumption formulas will be published in succeeding issues.—THE EDITORS.

A) Objective—Heating systems for low rent housing involve a variety of considerations, with one basic purpose—*the provision of suitable heating at the least possible cost to the tenant.* This objective is implied by the United States Housing Act of 1937, which requires rents (including the cost of heating) to be within the financial reach of families of low income. Since the heating expense may represent a very material portion of the total rent, or total expenditure for rent and household operation, economy in operating costs of the heating system is essential.

B) Selecting a Method of Heating—What method of heating and what type of heating system shall be used? Shall there be individual tenant operated heating units or shall heat be supplied from a central source outside the dwelling unit? These are questions which must be carefully considered. The choice should not be an arbitrary one. The advantages and disadvantages of each type and method should be carefully weighed. For example:

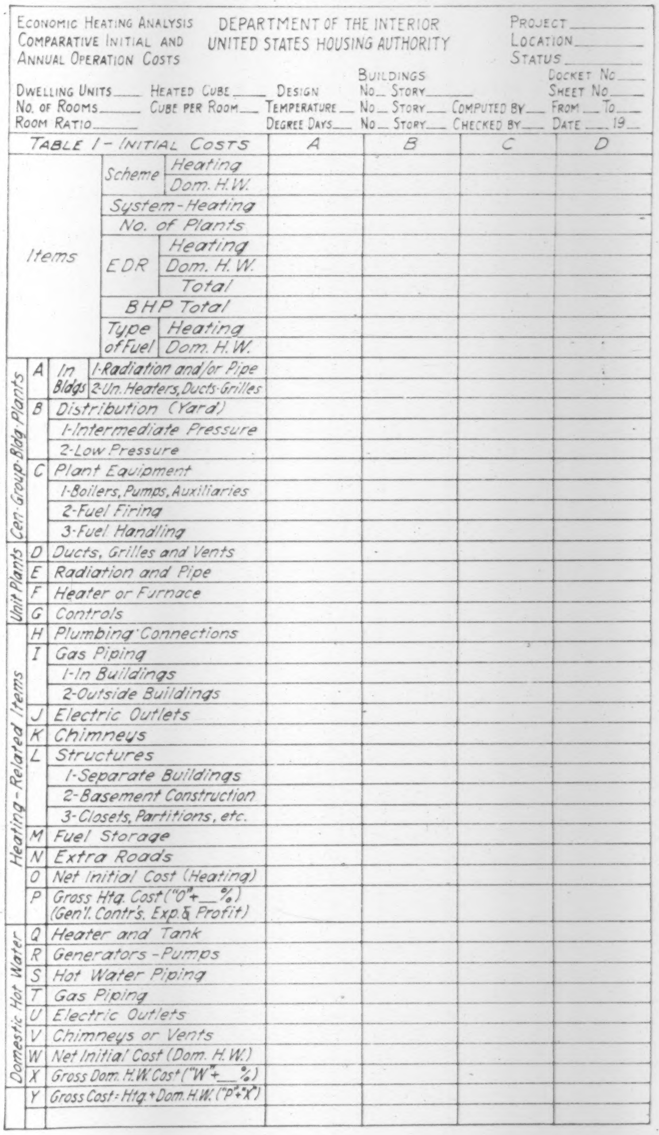
The individual unit places the responsibility for fuel consumption squarely on the tenant. It is obvious that when he pays directly for the fuel he consumes, he will be more economical in his use of heat, adjusting his consumption to his actual need and to his capacity to pay. Moreover, the assumption of this responsibility tends to make him a more responsible tenant in his other relations with the project.

On the other hand, we nevertheless find that, except in warm climates, the larger project operated plant will often cost less in operation, as it operates more efficiently, is usually equipped to burn cheaper grades of fuel, and fuel and supplies are purchased in larger quantities and hence at a much lower cost. Moreover, flats and apartments do not readily lend themselves to individual tenant operated plants, except when gas is available at a low rate. In cold climates there is also the danger of freezing the plumbing if the tenant fails to keep the heating plant operating.

Thus there are many factors to be evaluated and various methods of heating to be considered before arriving at a decision. At the outset, a survey of the methods which are suitable to the climate should be made and as many as possible of the factors affecting the choice should be evaluated in terms of dollars and cents. The wider the scope of the analysis, the greater the assurance that the ultimate decision will be the best one.

Because of the technical considerations involved it is usually important to have the services of a qualified heating engineer in the preparation of this analysis and in the final choice and the design of the heating system. An initial investment in qualified technical advice may pay for itself many times over in more accurate and dependable operating and maintenance estimates, greater speed in the preparation of working drawings, and greater operating economy and efficiency.

C) Factors Affecting Choice—(1) Initial cost and its effect on annual cost. (The added cost of providing space must not be forgotten.) (2) Annual cost: Operation, maintenance, repairs, replacements. (The choice of fuel used for domestic water heating and the use of the same fuel for other purposes may affect this item.) (3) Effect on site and building plan. (4) Continued availability of fuel and probable trend of its price. (5) Obsolescence and adaptability to change to overcome obsolescence. (6) Ease, safety, quietness, and cleanliness of operation.



ECONOMIC HEATING ANALYSIS
COMPARATIVE INITIAL AND
ANNUAL OPERATION COSTS

DEPARTMENT OF THE INTERIOR
UNITED STATES HOUSING AUTHORITY

PROJECT ____
LOCATION ____
STATUS ____

DWELLING UNITS ____
NO. OF ROOMS ____
ROOM RATIO ____

HEATED CUBE ____
CUBE PER ROOM ____

DESIGN
TEMPERATURE ____
DEGREE DAYS ____

BUILDINGS
NO __ STORY ____
NO __ STORY ____
NO __ STORY ____

COMPUTED BY ____
CHECKED BY ____

DOCKET NO ____
SHEET NO ____
FROM __ TO __
DATE ____ 19__

TABLE 1 - INITIAL COSTS				A	B	C	D
Items	Scheme	Heating					
		Dom. H.W.					
	System-Heating						
	No. of Plants						
	EDR	Heating					
		Dom. H.W.					
		Total					
	BHP Total						
	Type of Fuel	Heating					
		Dom. H.W.					
Cen.-Group-Bldg. Plants	A	In Bldgs	1-Radiation and/or Pipe				
			2-Un. Heaters, Ducts-Grilles				
	B	Distribution (Yard)					
		1-Intermediate Pressure					
		2-Low Pressure					
	C	Plant Equipment					
		1-Boilers, Pumps, Auxiliaries					
		2-Fuel Firing					
		3-Fuel Handling					
Unit Plants	D	Ducts, Grilles and Vents					
	E	Radiation and Pipe					
	F	Heater or Furnace					
	G	Controls					
Heating-Related Items	H	Plumbing Connections					
	I	Gas Piping					
		1-In Buildings					
		2-Outside Buildings					
	J	Electric Outlets					
	K	Chimneys					
	L	Structures					
		1-Separate Buildings					
		2-Basement Construction					
		3-Closets, Partitions, etc.					
	M	Fuel Storage					
	N	Extra Roads					
	O	Net Initial Cost (Heating)					
	P	Gross Htg. Cost ("O"+__%) (Gen'l. Contr's. Exp.& Profit)					
Domestic Hot Water	Q	Heater and Tank					
	R	Generators-Pumps					
	S	Hot Water Piping					
	T	Gas Piping					
	U	Electric Outlets					
	V	Chimneys or Vents					
	W	Net Initial Cost (Dom. H.W.)					
	X	Gross Dom. H.W. Cost ("W"+__%)					
	Y	Gross Cost-Htg.+Dom.H.W. ("P"+"X")					

(7) Effect on tenant responsibility. (8) Local practice and availability. (9) Climate.

Some of these factors relate to the type of system, some to the fuel, some to both. There may be other factors in particular cases.

D) Types of Systems: (1) *Individual Tenant Operated Unit*—In regions requiring only occasional heat, this should be the favored type. In climates more favorable to the project operated plant, the comparative economy of total fuel costs and the difficulties of fuel storage and handling must be considered.

Coal is usually considered impractical for use above the first floor, since it requires storage space and means for ash disposal. Unless provision is made to enable the tenant to purchase it at close to the wholesale price, its use will often prove uneconomic except for the stove type of heater. Soft coal presents a smoke nuisance.

Gas presents no storage or handling difficulties and, when low enough in price, makes the individual unit available for any type of dwelling.

Oil causes storage difficulties due to the fire hazard involved, except when basements are provided.

The common types of individual units and characteristics which affect their use are:

a) Fireplace or Circulator—When cold weather is occasional and not severe, this is the only method of heating which is justified. Fireplaces may be the ordinary masonry type or may have a metal chamber to permit the warming and circulating of air, and may have ducts to other rooms. Circulators may burn any fuel, depending upon local practice, availability, cost, and storage and handling facilities.

b) Stove—Does not permit uniform heat distribution or temperature control but may be suitable where very low cost and very low rent are the aims.

c) Gravity Warm Air—Low first cost; minimum of maintenance and adjustment; basement space required. (1) Pipeless: Very low first cost; distribution only partially effective; basement space required. (2) With ducts: Distribution more effective; ducts require space and replacement.

d) Forced Warm Air—Distribution most effective; no basement required; when gas or oil fired needs very little space; permits air filtering, humidification and automatic control at some increased cost and maintenance.

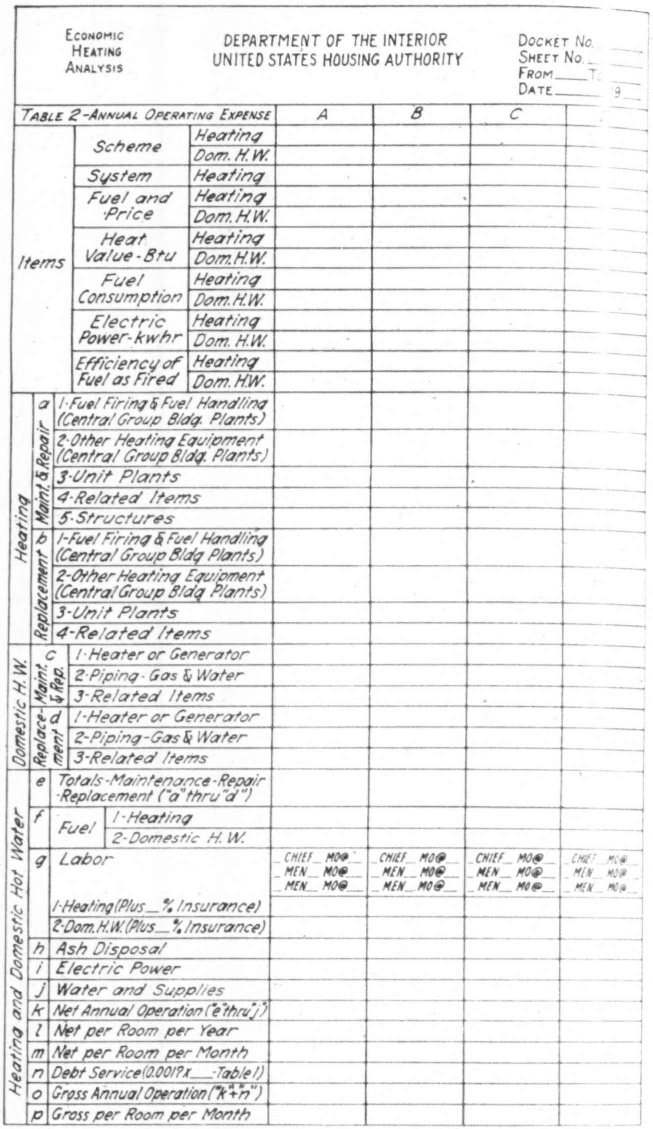
e) One Pipe Steam with radiators: Slightly higher in cost than gravity warm air; requires basement space.

f) Hot Water: Slightly higher in first cost than one pipe steam; very satisfactory in operation, particularly when a steady, moderate supply of heat is wanted; requires either basement or fire retarded utility room.

2) *Central or Group Project Operated Plants*—The major factors favorable to these types of plants are: (*a*) Concentration of dwelling units in flats and apartments and to a lesser extent in row houses. (*b*) Climate requiring nearly continuous heating for four or more months.

The decision between a single central plant and two or more plants, each serving a group of buildings, will be affected by: (*a*) The size and arrangement of the development and its topography. (*b*) The types of fuel available at low prices. (*c*) Labor rates and related factors.

A large central plant will usually require a separate building and high chimney. Although this may be undesirable for æsthetic reasons, the delivery, storage, and handling of coal and the disposal of ashes can be efficiently handled in such a plant.


ECONOMIC
HEATING
ANALYSIS

DEPARTMENT OF THE INTERIOR
UNITED STATES HOUSING AUTHORITY

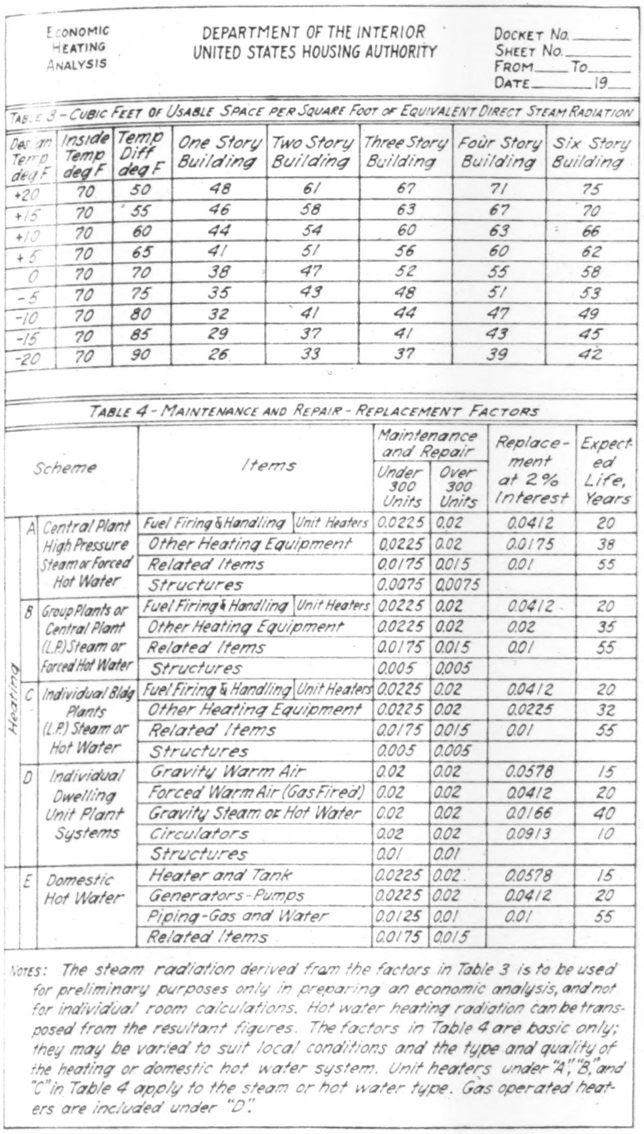
DOCKET NO.
SHEET NO.
FROM____T
DATE____ 19

TABLE 2-ANNUAL OPERATING EXPENSE			A	B	C	
Items	Scheme	Heating				
		Dom. H.W.				
	System	Heating				
	Fuel and Price	Heating				
		Dom. H.W.				
	Heat Value-Btu	Heating				
		Dom. H.W.				
	Fuel Consumption	Heating				
		Dom. H.W.				
	Electric Power-kwhr	Heating				
		Dom. H.W.				
	Efficiency of Fuel as Fired	Heating				
		Dom. H.W.				
Heating	a Maint. & Repair	1-Fuel Firing & Fuel Handling (Central Group Bldg. Plants)				
		2-Other Heating Equipment (Central Group Bldg. Plants)				
		3-Unit Plants				
		4-Related Items				
		5-Structures				
	b Replacement	1-Fuel Firing & Fuel Handling (Central Group Bldg Plants)				
		2-Other Heating Equipment (Central Group Bldg Plants)				
		3-Unit Plants				
		4-Related Items				
Domestic H.W.	c Maint. & Rep.	1-Heater or Generator				
		2-Piping-Gas & Water				
		3-Related Items				
	d Replacement	1-Heater or Generator				
		2-Piping-Gas & Water				
		3-Related Items				
Heating and Domestic Hot Water	e	Totals-Maintenance-Repair-Replacement ("a" thru "d")				
	f Fuel	1-Heating				
		2-Domestic H.W.				
	g Labor		CHIEF__ MO@__ MEN__ MO@__ MEN__ MO@__	CHIEF__ MO@__ MEN__ MO@__ MEN__ MO@__	CHIEF__ MO@__ MEN__ MO@__ MEN__ MO@__	CHIEF__ MO@__ MEN__ MO@__ MEN__ MO@__
		1-Heating (Plus__% Insurance)				
		2-Dom.H.W. (Plus__% Insurance)				
	h	Ash Disposal				
	i	Electric Power				
	j	Water and Supplies				
	k	Net Annual Operation ("e" thru "j")				
	l	Net per Room per Year				
	m	Net per Room per Month				
	n	Debt Service (0.0017 x___-Table 1)				
	o	Gross Annual Operation ("k"+"n")				
	p	Gross per Room per Month				

Group plants can usually be located in basements with chimneys related to the buildings; fuels such as oil or gas may be readily handled, regardless of the number, size and location of the plants. Group plants should be interconnected, wherever feasible, to permit more flexible operation and consequently greater economy in the low demand months. This is particularly important where coal is the fuel. The site plan should therefore be arranged to permit nearly uniform sizing of the group plants and their location for economical interconnection.

While these plants commonly distribute heat through radiators in each room, at least one housing project has successfully utilized the steam space heater, long used for non-residential heating. One unit heater, consisting of a steam coil over which air is blown by a motor driven fan, is used per dwelling unit. The cost for radiators, valves, and piping is reduced, but shorter life expectancy and motor repair for these heaters must be considered in comparing annual costs. Design factors will be found under "Steam Space Heaters."

Heating controls of the "continuous flow" and "on and off" and combination type used in group or central



ECONOMIC
HEATING
ANALYSIS

DEPARTMENT OF THE INTERIOR
UNITED STATES HOUSING AUTHORITY

DOCKET No.______
SHEET No.______
FROM____To____
DATE______19__

TABLE 3 – CUBIC FEET OF USABLE SPACE PER SQUARE FOOT OF EQUIVALENT DIRECT STEAM RADIATION

Design Temp deg F	Inside Temp deg F	Temp Diff deg F	One Story Building	Two Story Building	Three Story Building	Four Story Building	Six Story Building
+20	70	50	48	61	67	71	75
+15	70	55	46	58	63	67	70
+10	70	60	44	54	60	63	66
+ 5	70	65	41	51	56	60	62
0	70	70	38	47	52	55	58
– 5	70	75	35	43	48	51	53
–10	70	80	32	41	44	47	49
–15	70	85	29	37	41	43	45
–20	70	90	26	33	37	39	42

TABLE 4 – MAINTENANCE AND REPAIR – REPLACEMENT FACTORS

Scheme			Items		Maintenance and Repair		Replacement at 2% Interest	Expected Life, Years
					Under 300 Units	Over 300 Units		
Heating	A	Central Plant High Pressure Steam or Forced Hot Water	Fuel Firing & Handling	Unit Heaters	0.0225	0.02	0.0412	20
			Other Heating Equipment		0.0225	0.02	0.0175	38
			Related Items		0.0175	0.015	0.01	55
			Structures		0.0075	0.0075		
	B	Group Plants or Central Plant (L.P.) Steam or Forced Hot Water	Fuel Firing & Handling	Unit Heaters	0.0225	0.02	0.0412	20
			Other Heating Equipment		0.0225	0.02	0.02	35
			Related Items		0.0175	0.015	0.01	55
			Structures		0.005	0.005		
	C	Individual Bldg Plants (L.P.) Steam or Hot Water	Fuel Firing & Handling	Unit Heaters	0.0225	0.02	0.0412	20
			Other Heating Equipment		0.0225	0.02	0.0225	32
			Related Items		0.0175	0.015	0.01	55
			Structures		0.005	0.005		
	D	Individual Dwelling Unit Plant Systems	Gravity Warm Air		0.02	0.02	0.0578	15
			Forced Warm Air (Gas Fired)		0.02	0.02	0.0412	20
			Gravity Steam or Hot Water		0.02	0.02	0.0166	40
			Circulators		0.02	0.02	0.0913	10
			Structures		0.01	0.01		
	E	Domestic Hot Water	Heater and Tank		0.0225	0.02	0.0578	15
			Generators-Pumps		0.0225	0.02	0.0412	20
			Piping-Gas and Water		0.0125	0.01	0.01	55
			Related Items		0.0175	0.015		

NOTES: The steam radiation derived from the factors in Table 3 is to be used for preliminary purposes only in preparing an economic analysis, and not for individual room calculations. Hot water heating radiation can be transposed from the resultant figures. The factors in Table 4 are basic only; they may be varied to suit local conditions and the type and quality of the heating or domestic hot water system. Unit heaters under "A", "B", and "C" in Table 4 apply to the steam or hot water type. Gas operated heaters are included under "D".

plants have resulted in savings of up to 25 per cent of fuel costs. Design factors are given under "System of Heating Controls."

Part 1—Economic Analysis

A) Comparative Cost Analysis—Several suitable methods of heating having been tentatively selected, a comparative cost analysis should be made in order to determine which will result in the least expense to the tenant. The underlying principles involved in this analysis are simple and require no explanation. There are, however, certain common errors concerning which a reminder may be helpful.

Perhaps the most prevalent mistake is to overlook items of expense which are indirectly involved in the use of a specific type of fuel or heating plant. If, for example, coal fired gravity warm air systems are being considered, the cost of a basement or other space, coal storage space, chimneys, and possibly additional roads for the delivery of coal and removal of ashes, should be included.

If individual, group and central plants are being compared, there should be included not only the costs of boilers, breeching, auxiliary equipment, and piping, but also fuel storage space or tankage, construction costs of boiler and storage rooms and smoke stack, and heat insulation of boiler room ceiling. There may also be the cost of supply and return mains, with their supports and heat insulation and trenches or tunnels to nearby buildings and lines to hot water heaters.

The central plant should be charged with its building and smoke stack, as well as complete plant, distribution and return systems, and possibly cost of land occupied if additional land has to be acquired to accommodate the central plant.

With respect to items such as maintenance and replacement, the expense for which may vary widely, the greatest care should be taken to avoid estimates which are either unfairly pessimistic or unduly hopeful.

In general, the present prevailing costs will form the basis of computations, but unusual price conditions should be discounted and the long range trend anticipated wherever possible.

B) Forms for Analysis—Convenient forms for preparing the economic heating analysis are attached hereto. These are designed to facilitate separate analysis of plant and fuel costs.

Following are the items which are included in the attached economic analysis charts to determine the initial costs and annual operating expense:

Table 1—Initial Costs

Central-Group-Building Plants

A) Radiation and/or Pipe; Unit Heaters, Ducts and Grilles—in Buildings. Cost of heating system within the buildings, exclusive of equipment, auxiliaries and piping within the boiler room. Radiation can be estimated by reference to Table 3 of the charts.

B) Distribution (Yard). Cost of underground piping installation.

C) Plant Equipment. Cost of equipment, auxiliaries and piping within the boiler room. Automatic firing and fuel handling equipment should be noted separately. Building plants might include one boiler room per building or one boiler room per two or three small buildings.

Unit Plants

D-E-F-G) Cost of heating equipment for individual plants only. Items *D, E* and *F* might apply to warm air systems or circulators. Vents under *D* include fresh air connections. Items *E, F* and *G* are applied to steam or hot water heating systems.

Central-Group-Building—Unit Plants (Related Items)

H) Plumbing Connections. Cost of water and drainage required for heating system.

I) Gas Piping. Cost of proportionate share of gas piping applied to heating system.

J) Electric Outlets. Cost of electrical work necessary for heating system.

K) Chimneys. Cost of masonry flues, stacks and foundations.

L) Structures. Cost of structures, additional to dwelling facilities, necessary to house boiler and auxiliary equipment for central, group or building plants; closets, utility rooms, partitions, etc., for individual dwelling unit plants.

M) Fuel Storage. Cost of facilities for storing fuel. Fuel oil tanks concerned with the immediate operation of the plant or plants need not be included here.

N) Extra Roads. Cost of extra roads required in the delivery of fuel or removal of ash.

O) Net Initial Cost (Heating). Total of above items, each of which should include the sub-contractors expense and profit. However, it should not include general contractor's added percentage.

P) Gross Heating Cost. Net initial cost plus general contractor's added percentage.

Domestic Hot Water

Q to X inclusive) Costs of supplying domestic hot water. The same procedure should be followed as outlined heretofore for heating. It is necessary to note that when domestic hot water is supplied through generators, deriving its source of heat from boilers used also for space heating, the cost of the extra boiler capacity and heating distribution should be included in Items *A, B* and *C*.

Y) *Gross Cost* (*Heating plus Domestic Hot Water*). The summation of Items *P* and *X*.

Table 2—Annual Operating Expense

Heating and Domestic Hot Water

a through *d*) *Maintenance, Repair and Replacement.* The product derived by multiplying the initial costs from Table 1 by the factors set up for the respective items in Table 4. Related items generally refer to plumbing connections, gas piping and electric outlets.

e) The total of all maintenance, repair and replacement expense.

f) *Fuel.* Formulas have been prepared for estimating fuel consumption, which are incorporated in this bulletin. The influence on the rate structure in the use of gas for space heating and domestic hot water in coördination with that required for cooking and refrigeration should be applied in the analysis. Where the electric consumption for the operation of auxiliary heating equipment is a substantial amount, its influence on the electric rate structure should be thoroughly considered.

g) *Labor.* In high pressure boiler plant operation it may be necessary to employ the services of a competent first class licensed engineer. Local regulations may require such services continuously while the plant is in operation or for supervisory purposes only. In the latter case a portion only of the engineer's time might be devoted to the plant. In any event, it might be advisable to charge at full time the services of second class licensed engineers.

In low pressure plant operation licensed men are generally not required unless stipulated by ordinance or labor organization.

When plants require 24 hr daily operation, the personnel per shift (with the exception of the chief engineer if permitted by regulation) can be multiplied by 3½ times, which should compensate for relief time. If, on the other hand, the plants do not require operation on this basis, the staff could be reduced proportionately, with the necessary relief labor of approximately 16 2/3 per cent per man added. It is advisable that in preparing an analysis of different heating schemes before a selection is made, only that portion of the firemen's services actually required in the operation of the plant need be applied to it.

h) *Ash Disposal.* The expense of removing the ash from the project.

i) *Electric Power.* The expense of kilowatt hour consumption of all electric motor driven equipment.

j) *Water and Supplies.* The expense of water incidental to plant operation and supplies such as waste, lubricating oil, etc.

k) *Net Annual Operation.* The total of all operating expense (Items *e* through *j*).

l) *Net per Room per Year.* The net annual operation (Item *k*) divided by the number of rooms.

m) *Net per Room per Month.* The net monthly operation divided by the number of rooms.

n) *Debt Service.* The product of 0.0017 (which is the difference between the annual subsidy of 3.5 per cent and the interest and amortization of 3.67 per cent) by the Gross Costs in Table 1 of Heating (Item *P*), Domestic Hot Water (Item *X*) or the total of Heating and Domestic Hot Water (Item *Y*), dependent upon the nature of the analysis. No allowance has been made in the chart to compensate for any changes in these rates, since the influence of such fluctuations on the heating and/or domestic hot water per room per month operating expense would be negligible.

o) *Gross Annual Operation.* The summation of Items *k* and *n*.

p) *Gross per Room per Month.* The gross monthly operation divided by the number of rooms.

C) *Selecting the Fuel*—Choice of fuel is dependent in a large measure on local availability and cost. Other considerations are cleanliness and ease of handling. As the choice of fuel may affect the site plan and the management policy, an early fuel cost analysis should be made. A recommended form for preparing such an analysis is included in the "Economic Heating Analysis" chart attached, additional copies of which may be obtained upon application to the United States Housing Authority at Washington, D. C.

Low fuel prices are generally required to make individual heating units practical. There are several ways in which retail fuel prices may be lowered: purchase by the project at wholesale prices and resale to the tenants; group purchase sponsored by a "Tenants Association"; or purchase through the department which makes municipal purchases of fuel. The cost of handling fuel, including storage, weighing, delivering and billing, must be considered in any study of fuel purchasing methods. Fuel storage by the tenant may constitute a problem.

In the selection of fuel, especially coal, consideration should be given to a possible rise in price. The price of coal today is lower than it has been in a number of years.

[*To be continued*]

Maps Aid Air Conditioning Development

IN the March, 1938, HPAC, a market study for air conditioning was described under the heading "Air Conditioning Becomes Locally Competitive." In that connection a map of Chicago's busiest outlying commercial district, 63rd and Halsted Sts., was given. The map showed the location of each store, with the name, address, and types of business indicated. The air conditioned stores, of which there are 38 within two blocks in each direction from the corner of 63rd and Halsted, were shown by diagonal lines (cross hatching). Such a map is considered useful to air conditioning equipment manufacturers, sellers, and promoters. Direct by mail campaigns are helped considerably with addressing information supplied in this manner.

Eighteen Air Conditioning Centers

In furtherance of this idea, and because the map has proved so helpful, another map of one of the outlying business districts has been prepared. This district is known as Roseland, situated at 112th St. and S. Michigan Ave., about 12 miles south of the "loop." In the future it is intended to develop such a map for each business section where air conditioning has shown the most rapid acceptance. In all, there are 18 such centers in Chicago where air conditioning is being received actively. Similar maps of these 18 centers should represent the cream of the city's commercial air conditioning market.—WILLIAM P. ROCK* and KNIGHT C. PORTER*.

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*Air Conditioning Div., Commonwealth Edison Co.

Estimating Labor Costs for Piping Installations

By George E. Deatherage*

THERE are three piping labor estimating methods: (1) Estimating the actual materials in the job, plus the labor calculated as a percentage of the material. (2) Estimating the actual material required, plus the labor as figured from unit labor operations, such as the number of threads to cut, number of welds to make, etc. (3) Estimating the actual material on the job, plus an estimated labor amount for each line or branch, the basis of which is the practical experience and judgment of the estimator.

The Percentage Method

It is obvious that the ratio of labor to materials is a variable factor, depending upon the labor rate, material prices, efficiency of the labor, job conditions, type and number of hangers and supports, job interferences, and other such factors. Any percentage figures selected are bound to be more or less approximations, with the possible exception of their use by some firm that specializes on one piping classification, under practically the same conditions. An illustration of this might be the piping of a standard boiler set-up on a new installation, where the amount and type of piping is always the same. Even here, labor rates, freight rates and job conditions will cause differences. However, the greatest obstacle to this method is the attempt to use it on different piping classifications. Certainly no one would think of using the same labor to material ratio for both ferrous and non-ferrous piping, or for complicated instrument piping and a welded steam line. Nor could the plant maintenance engineer use the same ratio as the contractor. This method can only reflect accurate costs in few instances, and must be used with extreme caution.

Cost keeping, using the percentage method, becomes a simple procedure as compared to other methods, for all that is necessary is to total the cost of the piping materials and the labor that was required to install it. However, few contractors keep books in an exactly similar manner, and one may include items as labor that another carries as overhead. One might list compensation insurance as part of his labor cost, and another might carry it as an overhead item, or even in the material column. The percentage method, therefore, to be of maximum value involves the use of figures deducted from the same set of books. Insurance items alone may throw the figures off as much as 10 per cent.

Unit Operation Costs

As in the percentage method, we assume when using unit operation costs that the materials cost can be, and is, accurately determined from the take-off, and that the greatest unknown factor is the labor. An exception in this discussion is that of welded piping, which will be treated separately.

In using this method, the man-hours required to perform each separate operation are estimated. Thus, this method will entail separate figures for each operation on each type and size of pipe, and will vary with the type and material of the fittings. These unit operation figures must be based on accurate records, which require an enormous amount of clerical labor to secure, and even when secured, they cannot be used to very much of an extent except by the firm that compiled them.

Several years ago, the author made an attempt to arrive at individual unit operation costs on this basis, in the hope of discovering something new and useful in the general proposition of estimating and checking piping costs on several large industrial plants where the piping represented a major part of construction. Although the work was of many classifications, it was of the same general type, and large enough to warrant almost any expedient to make possible a more definite control of these expenditures.

In past years, all charges on the books to piping had been carried on one single account. It was first necessary to set up accounts for each size and type of piping, such as steel screwed, steel screwed seal welded, copper welded, aluminum welded, stainless steel welded, standard and extra heavy, etc. Some 200 separate accounts were necessary just to list the main operations on these piping classifications.

The main operations were broken down into what was called basic labor and auxiliary labor, the latter covering miscellaneous labor operations that appear on every job but are not basic piping unit labor operations. Standards for clamps, hangers, rollers, pipe supports, etc., had to be created in order to give them a basic value. A system of recording the actual labor and material in each unit had to be created from actual experience with numerous similar jobs, after which it had to be tabulated for purposes of job control and estimating.

The study resulted in unveiling considerable mystery as to some high piping costs. Out of it came a definite standardization for supports, a reduction in the types

The author follows up his discussion of preparing the piping estimate in the April HPAC with this general review of various methods of estimating the cost of labor in piping work. . . . He classifies the methods as the percentage method, unit operations costs, and materials plus estimated labor for each line or branch

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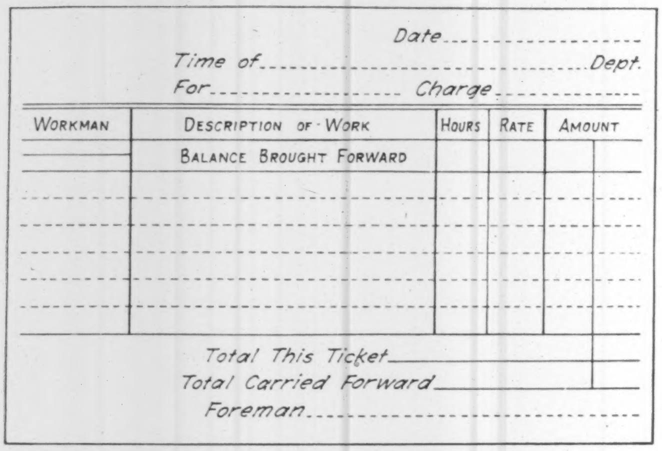
*Construction Engineer. Mr. Deatherage has been in charge of design, estimating and construction of mechanical installations over a period of some 25 years, most of his experience being in the piping field.



Date..................
Time of.................................Dept.
For..................Charge..................

WORKMAN	DESCRIPTION OF WORK	HOURS	RATE	AMOUNT	
	BALANCE BROUGHT FORWARD				

Total This Ticket
Total Carried Forward
Foreman..................

Fig. 1—Ticket for recording labor time

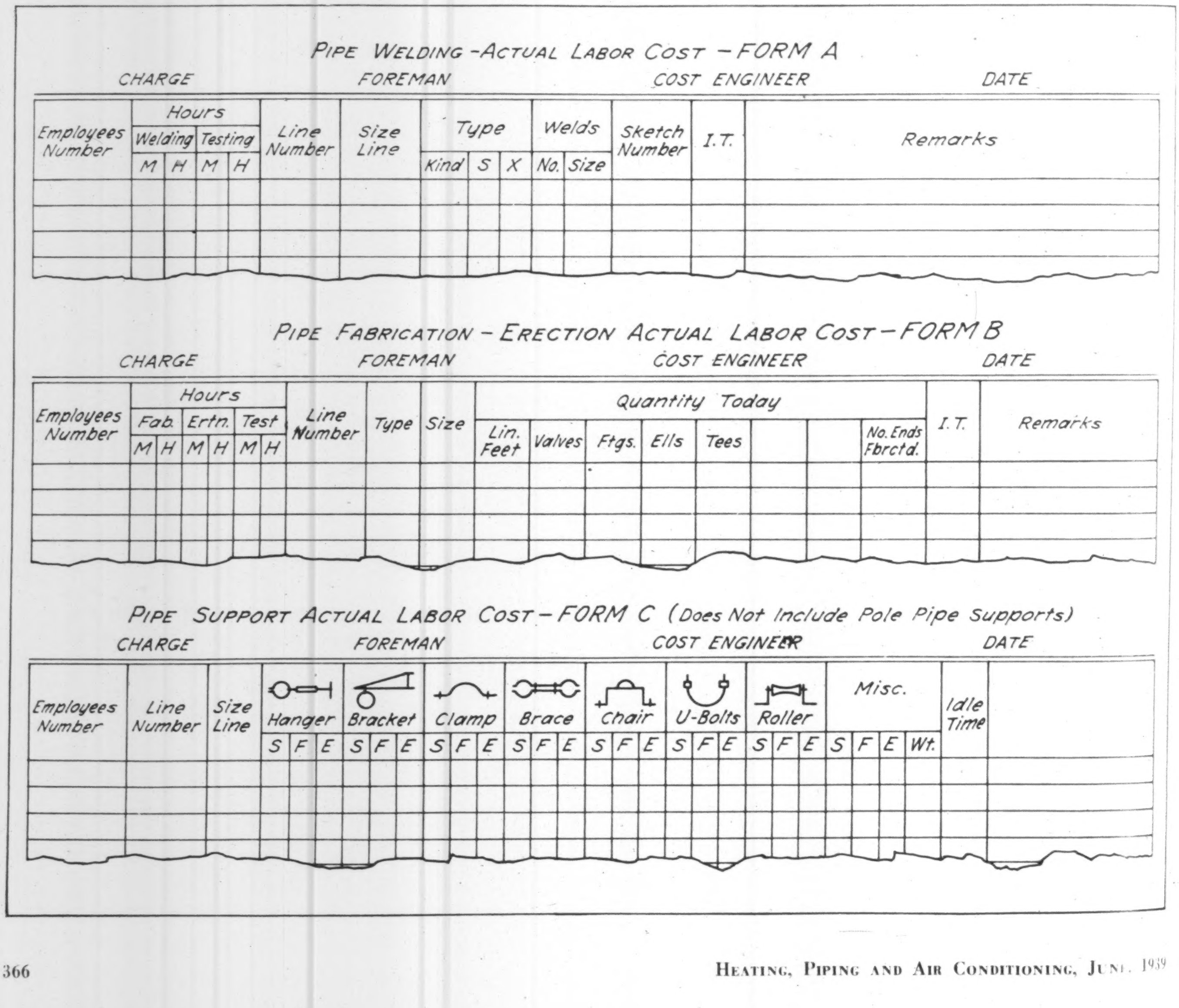
and makes of valves and fittings, standardization of gasket types, and a hundred other economies that were not previously apparent. In the main however, it does not seem that any universal method of valuing unit fabrication and erection costs that will embrace the whole category of piping in general can be expected. The variables are too many and the cost of securing and checking them greater than the benefit to be derived. Repetitive similar small operations might be so handled, but not the extensive industrial piping jobs as we know them today.

Materials Plus Estimated Labor for Each Line

This seems to be the most practical method, both in estimating and in recording job costs. If the lines or branches on the general piping plan have been numbered, the material can be taken off separately for each of them and priced, and the estimated man-hour labor can be checked by the percentage method. The piping foreman can, by looking over the individual line and the material sheets, isolate the larger items of unit operation and place a value on them, adding what in his practical judgment will be the man-hour labor to perform the balance of the work. Cost keeping then limits itself to recording the total labor on that line and branch against that estimated.

If the estimate has been broken down into complete detail, as it must be if it is to be accurate, such items as pole supports, hangers, expansion loops, cutting holes, excavation, handling and setting equipment, etc., appear as separate items for each line. As the materials are priced individually, so is the labor. The mere fact that each item is considered by itself in making the labor

Fig. 2—Forms for recording welded piping costs



PIPE WELDING - ACTUAL LABOR COST - FORM A

CHARGE FOREMAN COST ENGINEER DATE

Employees Number	Hours				Line Number	Size Line	Type			Welds		Sketch Number	I.T.	Remarks
	Welding		Testing											
	M	H	M	H			Kind	S	X	No.	Size			

PIPE FABRICATION - ERECTION ACTUAL LABOR COST - FORM B

CHARGE FOREMAN COST ENGINEER DATE

Employees Number	Hours						Line Number	Type	Size	Quantity Today								I.T.	Remarks
	Fab.		Ertn.		Test					Lin. Feet	Valves	Ftgs.	Ells	Tees			No. Ends Fbrctd.		
	M	H	M	H	M	H													

PIPE SUPPORT ACTUAL LABOR COST - FORM C (Does Not Include Pole Pipe Supports)

CHARGE FOREMAN COST ENGINEER DATE

Employees Number	Line Number	Size Line	Hanger			Bracket			Clamp			Brace			Chair			U-Bolts			Roller			Misc.				Idle Time	
			S	F	E	S	F	E	S	F	E	S	F	E	S	F	E	S	F	E	S	F	E	S	F	E	Wt.		

estimate reduces the chances of any large error creeping in, as is likely to happen with the percentage method.

One may extend the cost keeping from line or branch, recording the individual labor item costs for each classification or separate unit of work as it appears on the estimate. One may go as far as desired in checking the actual labor against that estimated.

A simple method of cost keeping is to have a ticket (Fig. 1) made out for each classification or item of work appearing on the estimate, on which is charged the man-hours spent on it for the day. The total labor for the previous day is added to the ticket, and the result is a continuous total of the labor spent to date on that item.

Welding Costs

Welded piping, by its very nature, is reduced to a smaller number of basic labor and material units, meaning fewer operations. This, coupled with the fact that most welded systems can be largely fabricated in the shop under definite shop conditions and control, and then taken to the job and assembled by the means of field welds or flanged connections, permits the practical use of unit prices per operation. These costs, therefore, are broken up into two main sub-divisions: (1) Shop fabrication costs. (2) Field assembly costs. If a shop is maintained, it is assumed that a bookkeeping system is in effect, similar to that of any commercial machine shop wherein accurate piece costs are available, and that the depreciation and overhead are known factors which enter into these costs.

Each section of welded piping, different in length, size and shape, is, in good practice, fabricated from a sketch, which if numbered and carrying a line or branch reference, permits definite cost piece identification. The costing is further simplified if the welders actually lay out and fabricate the entire section, as opposed to having layout men fabricate and tack weld preparatory to the actual welding.

Actual cost per weld will of course vary greatly in accordance with the method in use. If the fabrication is completed by layout men, up to the point that the tack welded section is turned over to the welders, the number of each size and type weld may be checked from manufacturers' tables or from experience on other welding on the same size pipe. However, if the welders' time includes that of cutting pipe to required lengths, assembly and tack welding of the fittings, and finally the completed welding, testing and checking of the section to required dimension, the total time per weld has no reference to experience outside of that particular shop.

In costing on this type of work, the factor of greatest variability is what is the lay out time, which covers the actual assembly of the pipe and fittings, including the tack welding and checking to print dimensions. The balance of the work, such as the number of cuts to make, bevels, tack welds, rolling or position welds, etc., are definite operations the costs of which are practically the same for each size and type of piping.

Fig. 2 shows various forms for recording welded piping costs.

The Consulting Engineer in Modern Construction

THE place of the consulting engineer in modern construction was discussed at the annual dinner meeting of the consulting engineers division of the Western Society of Engineers on May 15. The speakers included H. T. Heald, president of Armour Institute of Technology; Harry M. Hart, president of L. H. Prentice Co.; C. R. Ege of the Portland Cement Association, and Robert E. Hattis, consulting engineer.

Mr. Hattis said that he has rarely found an owner or an architect who, due to short-sighted policy, had any experience in building without proper engineering assistance, and who did not agree that it was expensive to do without such assistance. In building construction the owner profits, the architect enhances his reputation, and the contractor is able to do a creditable job at a profit where thorough engineering has properly coördinated the work. He quoted from an article by Dr. A. E. Morgan, until recently director of the Tennessee Valley Authority, on the subject of conclusive engineering analysis. In his article, Dr. Morgan pointed out the application and importance of conclusive engineering analysis and said that very often the weakest phase of engineering is not in refinement and accuracy of planning—important as they are—but in the preliminary process of determining the general character and design of engineering undertakings. Dr. Morgan felt that there is room in many fields of engineering for the specialist whose outstanding ability is creative imagination, disciplined by engineering principles and experience, and who can use that special ability with such order and discipline as not to become the despair of those who are responsible for bringing plans to fruition.

Mr. Hart discussed specifically the place of the consulting engineer in heating and air conditioning work. He pointed out that the engineer is called upon to design systems to produce certain definite results under conditions that vary in almost every building. He summarized the qualifications of consulting engineers as follows:

> They should have no financial interest in any of the products that are used in the installations they design.
>
> They are supposed to be the representative of the building owner but should have sufficient intelligence and experience to settle any disputes between the owner and contractor with fairness to both.
>
> They must of necessity be familiar with all the modern equipment available and know how to use it to the best advantage.
>
> They must also be familiar with all the city and state laws governing heating, ventilating, refrigerating, fire prevention, smoke elimination, occupational disease, sanitation, high pressure and electrical work.
>
> They must be familiar with the trade agreements of workmen so that they can properly allocate the work to the different trades involved so as to avoid jurisdictional disputes.
>
> They must have a general knowledge of the installation cost of various equipment as well as the operating cost in order to assure their clients a reasonable investment, commensurate with their needs.
>
> They should assume the responsibility for the proper performance of the system when it has been installed according to their plans and specifications and limit the guarantee of the contractor to that of remedying any defects in material or workmanship.

Studies of Various Firing Equipment Included in Air Pollution Survey

By **Frank A. Chambers***

THE Works Progress Administration recently embarked upon a comprehensive air pollution survey of Chicago and vicinity which is sponsored by Armour Institute of Technology, Lewis Institute and the city. The survey is a fact finding investigation, and it is hoped that through it suspicion, theory and predjudice concerning the possible harmful constituents of the atmosphere will be supplanted by definite established data as to the nature, composition, and effects of contaminants in the air.

The survey consists of six inter-related studies of various phases of the air pollution problem: (1) Visible smoke. (2) Dust and noxious gases in the air. (3) Origin of dust and noxious gases. (4) Ultraviolet and visible light penetration through the atmosphere. (5) Abstracting scientific literature dealing with air pollution. (6) Collection and codification of legal opinions and decisions affecting air pollution.

Study of Smoke

One division of the work is a study of smoke produced in all sections of the city by various classes of plants, employing many types of fuel burning equipment. The data obtained will be used:

(1) To compare the relative amount of smoke made by various classes of plants such as apartments, residences, boats, railroad, industrial and metallurgical.

(2) To compare present smoke conditions with those existing during periods when previous surveys were made.

(3) To compare relative air pollution in different sections of the city.

(4) To correlate smoke produced with various types of equipment and fuel.

In this division approximately 250 men have been assigned the duty of making smoke readings. They work in staggered shifts so that a complete performance of a stack can be obtained for a typical day running from 6:00 a. m. to 6 p. m. The information so gathered is tabulated and recorded on master punch cards. In addition to the smoke data, information on combustion conditions is recorded on each punch card, which represents an individual plant. With the aid of statistical machines, many statistical correlations are being made.

It is possible to obtain a correlation of smoke with any of the multiple possible combinations of type of plant, kind of fuel burning equipment, type of boiler, kind of coal burned, cause of smoke and atmospheric conditions at the time smoke was produced. In other words, at the end of the survey it will be possible to report on such problems as:

(1) The relative ability of various types of stokers to operate smokelessly.

(2) What difference exists between the various types of boilers in their ability to operate smokelessly.

(3) What difference in smoke emission exists between hand firing and mechanical firing.

(4) Variations in amount of smoke made by different fuels.

(5) Variation in amount of smoke made by different fuels burned in different types of equipment.

(6) Principal causes of smoke for various types of equipment.

Contaminants in Air

The second division of the study is an investigation of the contaminating constituents of the air. Analyses of concentration and particle size range of solids suspended in the air are being made. Determinations are being run of the amount, composition and nature of the dust settling upon the ground within the city limits. An attempt is being made to determine what per cent of this total amount originates from non-fuel-burning activities, for it is known that the air contains many solid particles that originate from such sources as wear of rubber tires on heavily traversed streets, sand and dust from stored building materials, rusting of iron and steel and many similar sources. At times dust storms over the midwestern plains have carried dust into the city.

Deposited dust is being examined under the microscope and with the aid of the spectroscope in an effort to find a method for identifying the source of such deposit. It is hoped that a new technique of soot identification can be developed which will be of value to air pollution authorities. There is some basis for the belief that each individual fuel burning plant leaves some distinctly characteristic marking upon the soot particles that its stack discharges. If a method of "finger printing" soot particles can be established, the work of smoke prevention officials will be simplified in their effort to trace the origin of soot nuisances. It is the intention of the survey to pioneer in this study.

The concentration of sulphur compounds in the atmosphere will be determined in selected representative locations under varying weather and wind conditions. The activity of these corrosive constituents will be the subject of an intensive investigation.

Sources of Contamination

Closely linked to the survey of atmospheric pollutants is the study of the sources of such contamination. The problem of excessive fly ash discharge by forced draft firing equipment is of concern to smoke abatement officials and to manufacturers of firing equipment who are required to conform to the regulations of these officials:

[*Concluded on p.* 370]

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*Deputy Smoke Inspector in Charge, Department of Smoke Inspection and Abatement, City of Chicago.

Rockefeller Center Adds Refrigeration for Increasing Air Conditioning Load

By C. W. Walton, Jr.*

To meet the air conditioning requirements of the most recently added buildings at Rockefeller Center, New York City, the original plant situated in the International building has been expanded as a central plant by the addition of a new 800 ton centrifugal refrigerating machine. The original plant comprised three 300 ton centrifugal machines in the sub-basement, with cooling towers on the roof. Space was provided in the original design for the addition of refrigerating capacity and for more cooling towers, and the piping in general, was installed to allow for such expansion.

The piping diagram of Fig. 1 shows the original layout. It will be noted that facilities were provided for supplying chilled water to various floors throughout the building, so that summer cooling could readily be obtained anywhere by simple, small central systems comprising fans, filters, coils and duct work with the necessary controls. This selective cooling system was divided into two zones and separated from the low pressure primary system by means of interchangers.

When the Time and Life building (No. 5) was constructed, there was still ample refrigerating capacity in the International building (No. 6). Hence, no refrigeration was added at that time. An interchanger was installed in building No. 5 for the stores' system and chilled water pipe lines from the International building plant were provided to take this load. Further increase in cooling requirements in the Time and Life building necessitated an additional interchanger. Simultaneously, more cooling units were added in the International building, so that by the end of the 1938 cooling season the 900 ton plant was well loaded.

Then the latest unit, the Associated Press building (No. 7) was constructed; it will require considerable refrigerating capacity during the 1939 cooling season. It was decided to put in the additional machine in the International building in the space which had originally been provided, as it could be conveniently installed to provide the cooling capacity required with some reserve for load expected in the near future.

Some modifications of the piping arrangement were made to provide chilled water to the several systems which operate under different pressure conditions; Fig. 2 indicates the scheme in its final form. It will be noted that the primary system was changed from a low pressure system with interchangers for higher pressures to an intermediate pressure system, with interchangers for the open spray systems, and for the extremely high level systems. All the air conditioning units are equipped with extended surface type cooling coils except for the stores in buildings Nos. 5 and 6, which are of the spray type; hence, all cold water circuits are closed except on these store systems. All of the

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*Mechanical Engineer, Rockefeller Center, Inc.

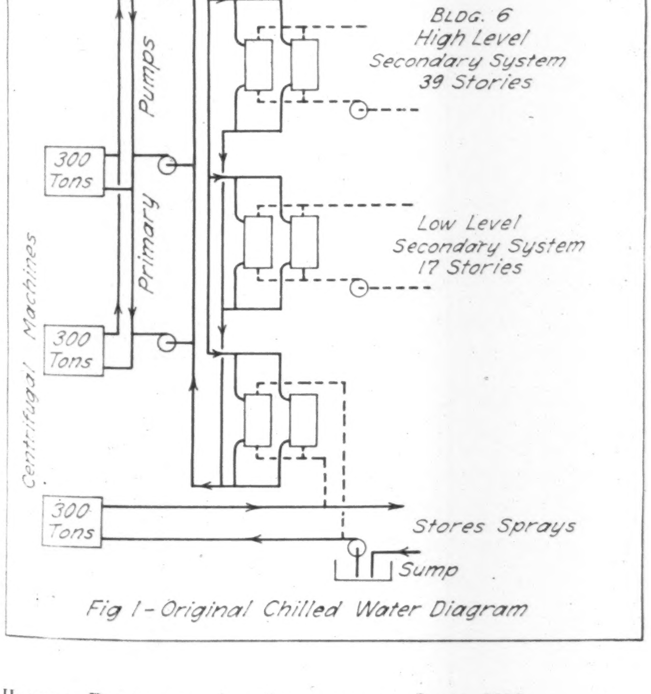

Primary Piping ———, Secondary Piping ---------
6 Interchangers
Bldg. 6
High Level
Secondary System
39 Stories
Low Level
Secondary System
17 Stories
Pumps
Primary
300 Tons
300 Tons
300 Tons
Centrifugal Machines
Stores Sprays
Sump

Fig I - Original Chilled Water Diagram

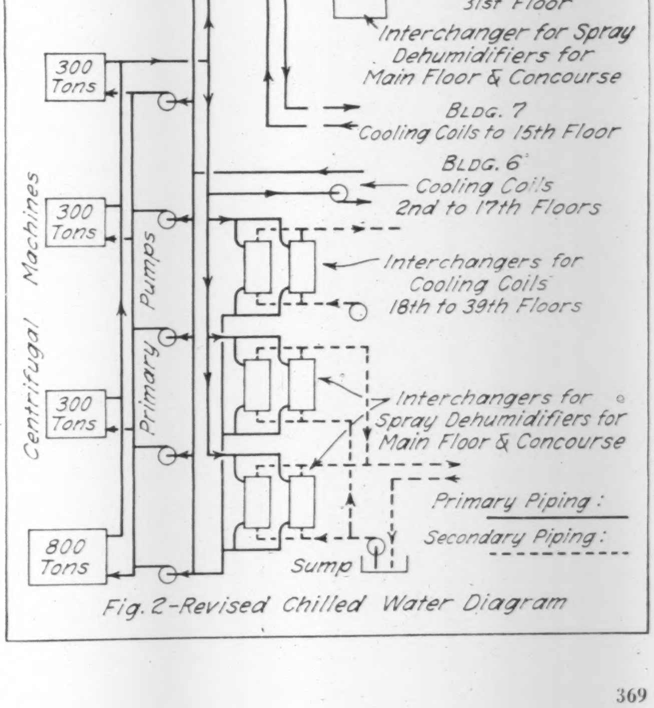
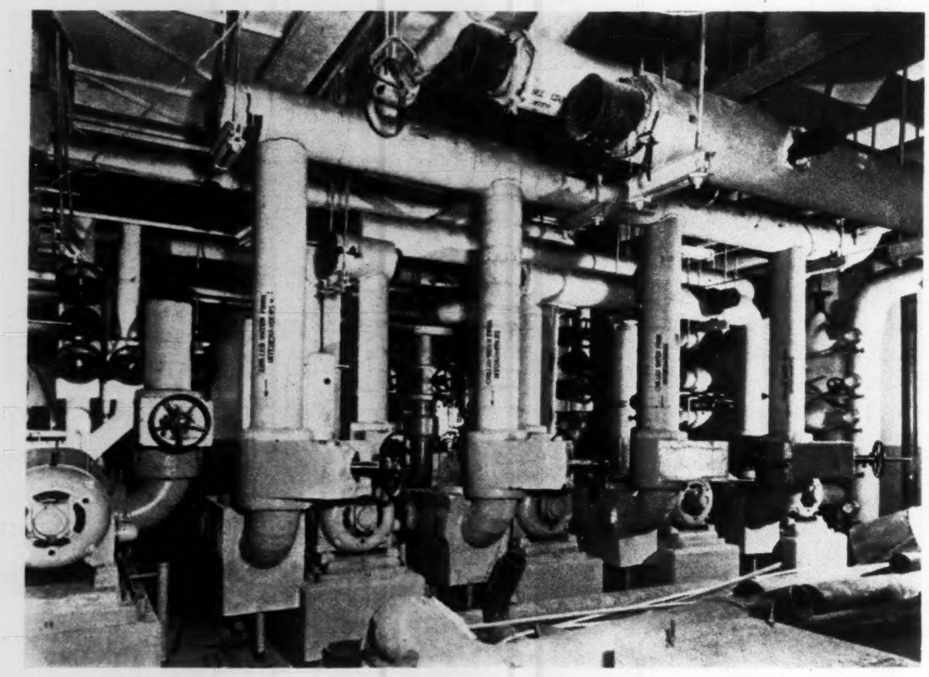

Bldg. 5
Interchanger for
Cooling Coils to
31st Floor
Interchanger for Spray
Dehumidifiers for
Main Floor & Concourse
Bldg. 7
Cooling Coils to 15th Floor
Bldg. 6
Cooling Coils
2nd to 17th Floors
Interchangers for
Cooling Coils
18th to 39th Floors
Interchangers for
Spray Dehumidifiers for
Main Floor & Concourse
Primary Piping :
Secondary Piping :
300 Tons
300 Tons
300 Tons
800 Tons
Centrifugal Machines
Primary Pumps
Sump

Fig. 2-Revised Chilled Water Diagram



Modifications of the piping arrangement were made

interchangers and pumps originally installed were adaptable to the final arrangement.

The plant was operated under partial load conditions in April, and was completed last month. Clyde R. Place was the consulting engineer, and Buensod-Stacey Air Conditioning, Inc., the contractor.

Further additions to refrigerating capacity will be needed for the 1940 cooling season to meet the increasing load conditions in existing buildings, and for the new 15 story Netherlands building (No. 11) now under construction. Still further additions are anticipated in the not too distant future for another new large building (No. 8), and for still further air conditioning demands in existing buildings.

Air Pollution Survey—

[*Concluded from page* 368]

there exists a demand for a simple method for making such determinations. The ideal test procedure should be readily adaptable to numerous stacks, take a short time to run and require the use of analysts of but slight technical training. No such method exists today. Moreover, no procedure has been accepted as standard. Several of the most promising methods are being used and it is hoped to find a suitable procedure. These fly ash determinations will be made upon the many combinations of boilers, firing equipment and fuels in use in the area so that conclusions can be drawn concerning rate of burning, furnace volume, turbulence, heat release, length of flame travel, initial and sustained temperature during flame propagation, re-radiating surfaces, water cooled surfaces, water cooled walls, fuel feeding equipment, size of coal, kind of coal, zoning of air blasts, baffling of boiler, and size and location of ash settling or collecting chambers.

The information obtained from this study will be made available and should be of value to the fuel user and the designing engineer. The advent of the now widely used spreader stoker has produced complaints of excessive fly ash discharge. Certain cities have gone so far as to ban the installation of such equipment. However, such action may result in higher cost of steam generation. A study such as this will undoubtedly lead to the establishment of definite facts as to what conditions will produce excessive fly ash discharge and whether abatement can be secured by the installation of dust collectors.

In addition to the determination of fly ash loadings from typical boiler plants, the following studies of sulphur compounds will be attempted:

(1) Variation in concentration of SO_2 in flue gas under different load conditions in the same plant, burning a given fuel.

(2) Variation in concentration of SO_2 under same load conditions, but with different types of equipment burning a given fuel.

(3) Variations in SO_2 concentrations in flue gas from constant load and equipment with various fuels.

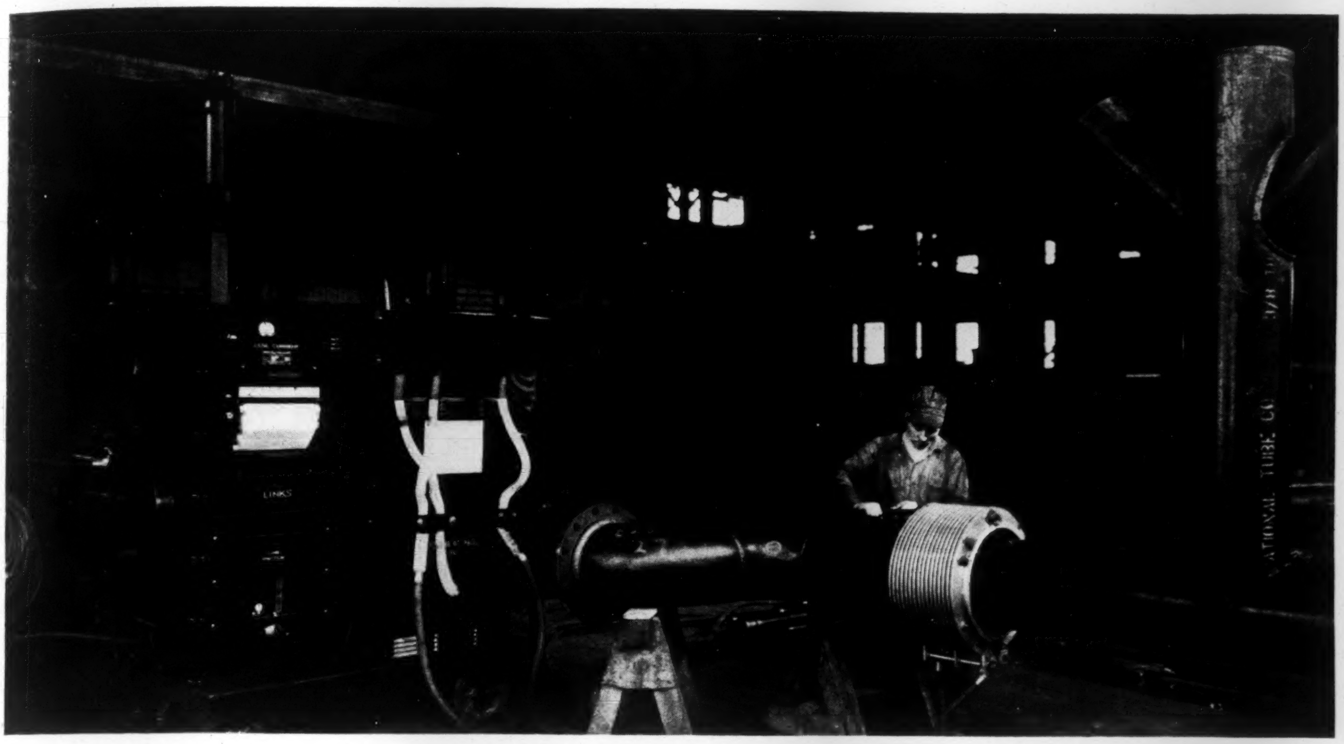
(4) Percentage of sulphur retained in waste removed from grate.

(5) Cause of visibility of discharge from chimneys burning high sulphur coals. A few years ago engineers of the smoke department showed that stacks serving plants burning high sulphur coals discharge a visible emission which varies from a light white haze to an almost opaque white cloud. This observation led to the theory that such visible emission was due to the condensation of sulphuric acid in the flue gas. An attempt will be made to establish the validity of this theory.

Another division of the study is devoted to an investigation of the ultraviolet and visible light energy reaching the inhabitants of the city during the four seasons. The causes of the depletion of anti-rachitic and erythemal doses of the sun's rays will be studied. The loss of ultraviolet energy will be correlated with the amount of smoke, dust and noxious gas in the atmosphere. Twenty-five stations will be used to secure measurements of ultraviolet and visible light energy. The procedure is based on the methods used and recommended by the U. S. Public Health Service.

Yet another division of the project is to review the existing literature on air pollution and make such information easily available to the engineer.

The final division of the project will attempt to codify legal opinions, interpretations, rules, regulations and standards dealing with air pollution both in the United States and abroad. Such information will be located, cataloged, abstracted and inter-indexed.



Stress relieving a piping weld in the shop

Fabrication Details for Welded Piping

F. P. Woumans* discusses economy in the fabrication of high pressure and high temperature steam piping as affected by design of the welded joint and the backing rings, presenting his views on proper procedures

MUCH has been written and said on the subject of the design, welding and fabrication of piping for high pressure and high temperature with carbon moly steel, or heavy wall thicknesses of carbon steel, pipe. The welding problem has been solved, and welding procedures for both classes of this piping are available that, if properly applied, assure the strength of the welded joint.

In the author's opinion, one of the principal ways of achieving economy in fabrication of such piping is by eliminating the necessity for upsetting the pipe to increase its section at the welded joint. (Figs. 1 and 2 show typical sections of upset pipe). The expense of this operation can be done away with by using a properly designed joint welded by a correct procedure. The pipe—whether it be carbon steel or carbon moly—should be preheated and the temperature should be maintained while the weld is being made.

Carbon molybdenum steel pipe ½ in. thick or over and carbon steel pipe ¾ in. thick or over should be stress relieved. On carbon molybdenum steel pipe, the welded joint should be stress relieved as soon as possible after the weld is completed. Accurate preheating and stress relieving is important, and it should not be necessary to guess at the temperatures. The picture at the top of the page shows a weld being stress relieved by an electric induction stress relieving machine having close temperature control, and automatically recording the temperature during the entire process. This machine also is used in preheating, by either the induction or resistance process.

It is the writer's opinion that a correctly designed joint for field welds and for shop fabrication is one such as shown in Fig. 3. The weld as given in the recommended practice of the ASA sectional committee is shown in Fig. 4. Both these types of welded joints have proved of ample strength, and under test the base metal has failed before the weld.

Backing rings are mainly used to permit sufficient separation of the pipe ends to enable the welder to penetrate to the inside of the pipe wall without getting weld spatter and icicles inside of the pipe. They aid also in aligning the pipe, although this factor can be overlooked.

Economy should be given consideration in connection with the use of backing up rings. It is the author's belief that they are not so important in shop fabricated piping, where the weld can be cleaned on the inside of the pipe upon completion. However, in the field, and with shop welds where access to the inside of the pipe after the weld has been made is impossible, a backing up ring becomes desirable.

Care should be taken in their selection. For pipe less than 6 in., a diagonal split ring with a ⅛ in. wide raised shoulder in the center has proved generally acceptable. For 6 in. pipe and over, a closely fitted machined ring is shown in Fig. 5. Backing up rings about 2 in. wide have been used, and while they fulfilled their purpose—keeping spatter and icicles out of the pipe—they created another obstacle. During the welding process the heat affected these rings to such an extent that they drew away from the pipe at both ends, thus reducing the area and making a water trap. It is a matter of record that in some instances corrosion broke up these rings, and pieces found their way into machinery. Research has indicated that a narrow ring of proper design is not only economical but desirable. The ring as shown in Fig. 5 has proved highly successful and when used in a joint as shown in Fig. 3 will not back away from the pipe during the welding or stress relieving process. These rings, while comparatively easy to make, also reduce the cost of boring the pipes, thus effecting another economy.

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*Chief Engineer, Power Piping Div., Blaw-Knox Co.

The joint of Fig. 3 is economical in construction without sacrificing strength, and by carefully examining the welding groove, it will be noted that while some material has been removed for the backing up ring, the groove has been designed so as to give a maximum of welded metal, which, due to its superior quality as compared to the basic material, more than makes up for the material removed. In addition, an added layer about $\frac{3}{16}$ in. thick extending beyond the width of the welding ring is an additional safety factor. However, in all our tests this added material has been removed before pulling the sample, and at no time has the failure been in the weld.

The ring, being ⅛ in. in thickness, is set in the pipe which has been recessed $\frac{1}{16}$ in. deep, adding ⅛ in. to its nominal diameter. Advantage is taken of the extra thickness usually present in high pressure piping. This extra thickness over the minimum required for the specific pressure in the piping can be removed without encroaching on the safety of the pipe. The usual under thickness allowed in manufacture of pipe is around 12½ per cent, and as this variation is on the inside, there is usually more than enough material available for recessing the pipe.

[For further information on backing rings, the reader is referred to the following articles which have appeared in HEATING, PIPING AND AIR CONDITIONING: Fabrication Details for High Pressure and Temperature Piping, by Arthur McCutchan, March, 1939; Use of Backing Rings in Welding High Pressure, High Temperature Piping, by Sabin Crocker, July, 1938; Design and Fabrication of High Pressure, High Temperature Piping, by F. C. Fantz, May, 1938; Weld Design for High Pressure, High Temperature Piping, by J. H. Deppeler, June, 1938.—Ed.]

Figs. 1 and 2—Typical sections of upset pipe. . . . Figs. 3 and 4—Designs for welded joints. . . . Fig. 5—Design for backing rings

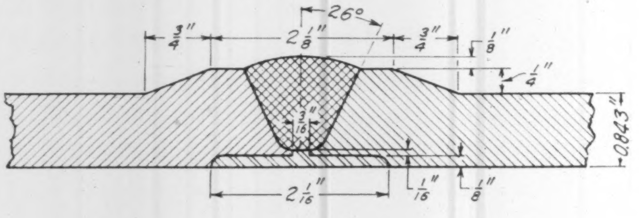

26°
3/4"
2 1/8"
3/4"
1/8"
1/4"
3/16"
0.843"
2 1/16"
1/16"
1/8"

Fig. 1

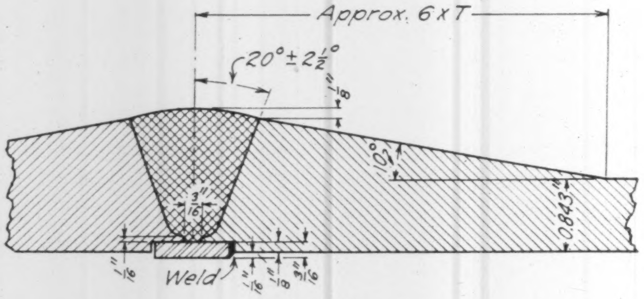

Approx. 6 x T
20° ± 2½°
1/8
10°
3/16"
0.843"
1/16
Weld
1/16
1/8
3/16

Fig. 2

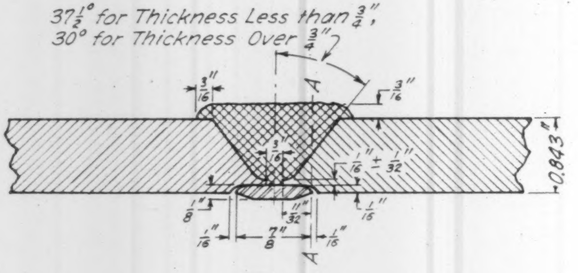

37½° for Thickness Less than 3/4",
30° for Thickness Over 3/4"
A
3/16"
3/16"
3/16"
0.843"
1/16" ± 1/32"
1/8"
11/32"
1/16"
1/16"
7/8"
1/16"
A

Fig. 3

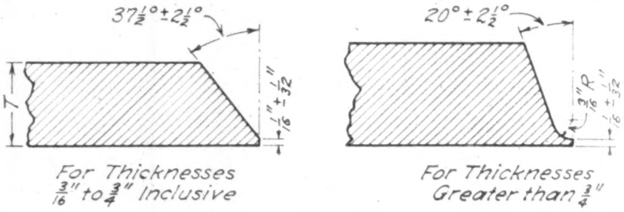
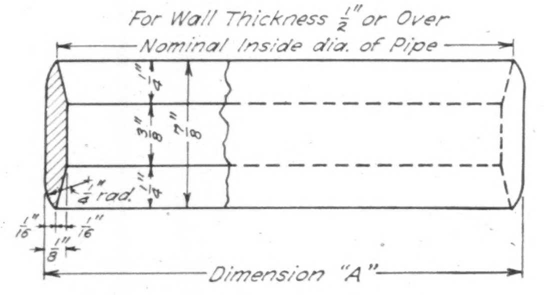

37½° ± 2½°
T
1/16" ± 1/32"
For Thicknesses
3/16" to 3/4" Inclusive
20° ± 2½°
3/8" R
1/16" ± 1/32"
For Thicknesses
Greater than 3/4"

Fig. 4


For Wall Thickness 1/2" or Over
Nominal Inside dia. of Pipe
1/4"
3/16"
7/8"
1/4"
1/4" rad.
1/16"
1/16"
1/8"
Dimension "A"

Dimension A

Pipe Size	Schedule No. for Wall Thicknesses (A106-36)							
	30	40	60	80	100	120	140	160
4							3.565	3.565
5					4.690	4.690	4.440	4.440
6					5.625	5.625	5.215	5.215
8				7.750	7.565	7.215	7.125	6.940
10			9.875	9.690	9.440	9.190	8.875	8.625
12			11.750	11.500	11.190	10.875	10.625	10.250
14			12.940	12.625	12.250	12.000	11.625	11.215
16		15.125	14.815	14.440	14.065	13.690	13.250	13.000
18		17.000	16.690	16.250	15.815	15.440	15.000	14.625
20	19.125	18.940	18.500	18.065	17.625	17.125	16.625	16.250
24	23.000	22.750	22.250	21.690	21.125	20.625	20.000	19.450

Fig. 5

Planning an Operating Schedule to Save Building Heating Steam

By Charles N. Bailey*

Preventing the overheating of buildings by operating the heating plant in accordance with the weather instead of the calendar is well worth the time and small investment required, according to the experience of Aldis & Co. . . . How to plan such an operating schedule and the economies possible by using it are described here

WHEN building heating plants are operated from the calendar instead of the weather, overheating and waste of fuel or steam dollars results. One cause of overheating dates back to the days when office buildings had steam pump operated hydraulic elevators or other equipment which resulted in an excess of low pressure exhaust steam. With such steam available for heating in quantities greater than needed, there was no particular reason to worry about conserving it. Enough steam was supplied to keep the buildings plenty hot in order to ward off any tenant complaints about being cold.

When it is desired to break down such barriers of custom and launch a heat economy program, it is necessary for those who supervise the building heating to do more than merely instruct the operating force to be more careful. A heating schedule should be made up for the particular building under consideration which will assure that steam will be used in the proper quantities and without wastage.

Obtaining and Using Temperature Records

A simple yet effective way of laying out a heating schedule is with the use of a small portable recording thermometer. This can be placed in different offices on consecutive days, thereby producing a record of the temperature conditions throughout the building. These instruments cost but little and have been the means of saving thousands of dollars each year. The best comparison one can make to determine whether heat is being wasted is the temperature maintained within the building. The often used units of heat economy based on building volume, wall space, degree days, or equivalent square feet of direct radiation are useful for analysis; but if the building has a special heating problem such as high ceilings, large windows, ventilating systems or special occupancy, it should not expect to equal the records of buildings with less severe heating problems.

In the interest of comparison of past and future conditions, the temperature records should be started before any changes are made in the heating method. The thermometer records show not only the temperatures throughout the day but also the length of time required to warm the building in the morning, which of course varies with the outside temperature, the rate of temperature drop after the steam is turned off, and the total hours of heating for the day. Heating above 72 F and heating during unoccupied periods, such as early in the morning and late at night, are very definitely wasteful. If a building does not open for business until 9:00 a. m., why should it be heated to 70 F by 6:00 or 7:00 a. m.? If the building closes generally by 6:00 p. m., why should it be kept warm until 10:00 or 11:00 p. m.? Such practice just adds six to eight hours of extra heating and accomplishes nothing.

After a good many charts have been scribed, a graph showing the proper time to start heating according to the outside temperature can be made up by plotting the starting times against various outside temperatures. The early morning temperature can be taken each day from a thermometer placed outside the building or, if available, from a weather bureau chart. When the thermometer charts show that three hours are required to raise the building to 70 F when the outside temperature is 30 F, then the ordinate on the starting time graph would be 9:00 a. m. minus three hours or 6:00 a. m. and the abscissa would of course be 30 F. Also when the charts show that only one hour is required to warm the building when the outside temperature is 50 F, then the ordinate is 8:00 a. m. and the abscissa is 50 F. If several points are plotted in this manner, a straight line can be drawn through their averages to give the time of starting for various outside temperatures. This first graph may have to be revised somewhat after it has been in effect for awhile; however, if enough points are plotted the graph will be found to be quite accurate. The greater the spread of the outside temperatures during the trial period the greater the accuracy of the graph. The graph should be extended to cover all extremes of temperatures that may be met, even though they were not experienced during the trial period.

Fig. 1 shows the hit-and-miss type of heating in a building before the starting schedule was put into effect. Notice that the room temperature reached 79 F on Wednesday and Friday and from the shape of the curve on Thursday the temperature would have reached 79 F if the tenant had not opened his window. Also notice that on Wednesday the building temperature reached 70 F at 6:30 a. m., on Thursday at 8:00 a. m. and on Friday at 7:30 a. m. These three days show a total of five hours of unnecessary warming up time. On each of the three days the steam was shut off at 5:30 p. m. but the heat in the building carried over for long periods. On Wednesday night the temperature did not fall below 70 F until 7:00 p. m., on Thursday night not until 4:30 a. m., and on Friday night not until 3:00 a. m. Now again this building does not need to be heated after

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*Assistant to the General Superintendent, Aldis & Co., Building Management.

6:00 p. m. so the steam could be turned off at such a time that the temperature would drop to 70 F by 6:00 p. m. Consequently the night overheating amounted to one hour, 10½ hours and nine hours, or a total of 20½ hours. The unnecessary heating time shown for the three days totals 25½ hours, which is staggering when compared with the nine hours per day or 27 hours of necessary heating.

Fig. 2 shows the results of scheduling the starting and stopping time for heating. Overheating has not yet been fully controlled, but note how accurately the warm up line crosses the 70 F line at 9:00 a. m. Also note the reduction in the evening carry-over. This chart shows 9½ hours of unnecessary heating.

Fig. 3 shows further improvement in controlling the overheating. The maximum temperature of 74 or 75 F does not occur until nearly 6:00 p. m. and indicates the steam should be turned off earlier. The carry-over also shows that the steam should be shut off earlier, but this chart is a very definite improvement over Fig. 1 and the savings have been very nearly in proportion to the figures shown. The pounds of steam per degree day have dropped from 4350 for Fig. 1 to 3390 for Fig. 3. This represents a seasonal saving of 6,048,000 lb. based on 6300 degree days per season.

Heating System Repairs

When heating steam is used sparingly, some rooms will be found that require extra radiation and others where the radiators will require new valves, air vents, traps, or repairs to the piping. The added expense of these repairs will be easily justifiable by the steam savings and they will not be a repeating item. Quite a bit of time should be spent by the engineering crew in checking conditions throughout the building. Thermometers should be installed at accessible key points to help the men control temperatures during the day. It probably will help the fireman if the starting time graph is copied into tabular form, as most basement men prefer getting information from a table to using a graph. A special deviation from the normal starting time will be required on days following holidays. The extra warm up time required will have to be determined by experiment, but it will usually amount to about an hour.

If the steam is well controlled during the day and the building does not become overheated, the shut-off time will be close to 5:00 p. m. over a wide range of outside temperatures. A shutting down schedule cannot be determined finally until after the daily practice has been established.

Controlling the Steam

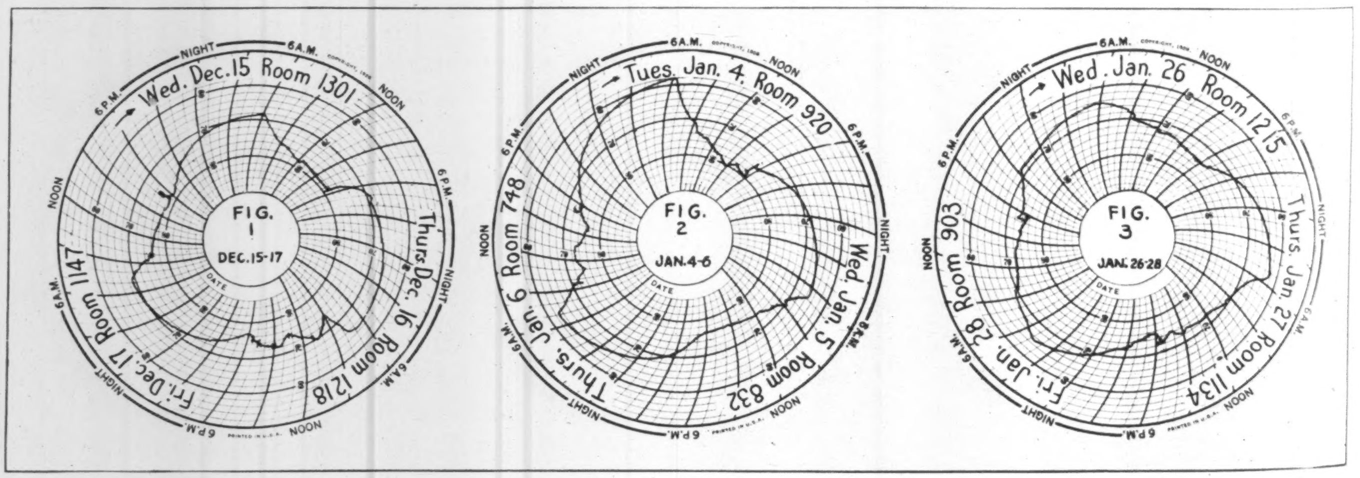
The method of controlling the steam during the day will depend upon the type of heating system and the equipment at hand. With a vacuum system, a simple method is to control the flow of steam by varying the differential or by changing the initial steam pressure. An intermittent type of valve is sometimes placed in the main steam line and controlled from a mechanical or thermal timing device. With one pipe, stoker fired steam plants a simple solution is to shut down the stoker either manually or mechanically for varying periods.

The hand fired furnace is the most difficult to control and will entail some study on the part of the engineer. Probably the fires can be regulated with the drafts to give good economy, or the pressures may be controlled to vary the heat in the building. One thing to guard against is the so-called "apartment house style" of heat regulation, wherein the building temperatures vary greatly during the day.

It is usually unnecessary to install automatic controls to achieve—at least partially—the *kind of savings outlined here*, as most plants have one or two hand operated valves that can be used to control the steam flow to the building. Valve mechanisms that are thermally, mechanically or clock operated may of course make additional savings, but for smaller buildings at least a part of the possible savings can be had by well-planned manual operation.

The advantages of constantly watching the heating bills are worth the time required and the small investment may pay enormous dividends.

Fig. 1—Hit-or-miss type of heating in a building as shown by temperature chart before starting schedule was put in effect. . . . Fig. 2—Results of scheduling the starting and stopping time for heating. . . . Fig. 3—Further improvement in control of overheating is illustrated by this temperature chart



NFPA Revises Its Regulations for Air Conditioning Systems

REVISIONS of its Regulations for Air Conditioning and Blower Systems, 1938 edition, were adopted by the National Fire Protection Association at its annual meeting last month at the Stevens Hotel, Chicago. They were submitted as the 1939 report of the committee on blower systems.

The discussion on the committee report was devoted entirely to the wording of the reference to be given in the regulations to the American Standard Safety Code for Mechanical Refrigeration, the question being whether the regulations should adopt the code in its entirety or should make advisory reference to it. The exact wording of the paragraph (No. 191) on the point was referred to the board of directors.

In his remarks when presenting the committee report, the chairman, C. W. Wheelock, said that the question of effective cleaning of ducts is one of the important matters for the next year's work. He mentioned also the photo-electric method of detecting smoke and said it was regarded as one of the best means of shutting off air flow.

Following are the revisions of Part 1 of the regulations, which pertain to installation of air conditioning and ventilating systems in buildings other than residences, adopted by the NFPA:

110. Construction of Ducts.

114a. *Revise the second paragraph to read:*

Work involving the use of torches shall not be undertaken on ducts until the system has been shut down, the duct cleaned and all combustible lining and covering material has been removed from the portion of the duct being repaired.

117. *Revise this paragraph to read:*

117. Return ducts, other than vertical, shall be so constructed that the interior is accessible to facilitate the cleaning of possible accumulations of dust and combustible material in them, except that accessibility is not required where all of the following conditions prevail:

(a) The occupancy is not productive of combustible material, such as lint, dust, greasy vapors, etc. Such occupancies are banks, office buildings, churches, hotels and institutions (but not kitchens, service rooms and manufacturing portions).

(b) The return openings are at least 7 ft above the floor or are protected by corrosion-resistant metal screens of at least 14 mesh installed back of the grilles so that they will not draw in papers, refuse, cigarettes and other combustible solids.

(c) The minimum design velocity in the return from the particular occupancy is 1000 ft per minute.

Clean-out openings at approximately 20 ft intervals shall be provided where accessibility to facilitate cleaning is required and where the ducts are smaller than 18x24 in. Removable grilles may be accepted as clean-out openings.

Supply ducts, other than vertical, shall conform to the above regulation for return ducts, unless all of the supply air passes through either water spray or filters.

130. Automatic Fire Doors and Dampers.

135. *Revise to read:*

Where ducts pass through floors, approved fire dampers shall be provided as follows:

(a) Where such ducts serve only one floor, only one fire damper shall be required in the main supply duct from the unit and only one in the return.

(b) Where such ducts serve two or more floors, fire dampers shall be required at each direct outlet or inlet and in each branch duct at its junction with the main vertical duct. Dampers are not required at room openings in the branch duct.

Dampers provided in ducts used solely for exhaust of air to the outside, shall be installed in such a way that they will not interfere with the flow of air in the main duct. No dampers are required in a system serving only one floor and used only for exhaust of air to the outside. Dampers should be designed to close in the direction of air flow.

136. *Revise to read:*

136. Fresh air intakes shall be protected with approved automatic fire doors or dampers except where permission to omit them, because of light exposure, is granted by the inspection department having jurisdiction. When deemed necessary by inspection department, approved heat actuated devices shall be installed at intake openings to shut fans down in case of exposure fires.

140. Air Intakes and Outlets.

142. *Revise to read:*

142. Discharge and exhaust air openings and recirculating air intakes shall be located at least 3 in. above the floor, except that protected floor inlets may be permitted, under seats, in theaters. When located less than 7 ft above the floor, inlet and outlet openings shall be protected by a substantial grille or screen, through the openings in which a half inch sphere will not pass.

143. *Insert new paragraph to read:*

143. Fresh air intakes shall be protected by screens of corrosion-resistant material not larger than one half inch mesh.

144. *Insert new paragraph to read:*

144. Care should be exercised in choosing the location of fresh air intakes to avoid drawing in combustible material and to minimize the hazard from fires in other structures.

150. Air Filters.

151. *Revise to read:*

151. (a) Air filters shall be of a type that will not burn freely or emit large volume of smoke or other objectionable products of combustion when attacked by flames.

NOTE. The smoke producing characteristics of the filter should be considered in relation to the occupancy of the building in which it is installed, the kind, nature and air handling capacity of the installation, and whether or not the installation is of the central station or unit type and to the protective features if and when provided.

The discharge of smoke is particularly serious as a panic hazard in buildings which may be occupied by large numbers of people, such as theaters, auditoriums, department stores, etc. It is also serious in occupancies which contain stock particularly susceptible to smoke damage.

(b) The installation of approved automatic extinguishing equipment employing water, gas or other approved means in the enclosure of the air conditioning system to protect against combustion of material that may accumulate is recommended for systems other than those of the unit or cabinet type with blower capacity not exceeding 20,000 cfm and which supply only one floor area or a portion thereof. Where sprinklers are installed, suitable provision should be made for drainage. In buildings not equipped with automatic sprinklers, the water supply may be taken from the house piping, if the supply is adequate for the purpose.

153. *Substitute words* "liquid adhesives" *for word* "oil."

154. *Substitute words* "liquid adhesives" *for word* "oil."

155. *Revise to read:*

155. All air filters shall be kept free of excess dust and combustible material. Unit filters shall be renewed or cleaned when the resistance to air flow has increased to five times the original resistance or when it has reached a maximum of 0.5 in. water gage, whichever is higher. A suitable draft gage should be provided for the purpose. Draft gages of a type which will operate a warning light or produce an audible signal when excessive dust loads have accumulated, are recommended. If the filters are of the automatic liquid adhesive type, sludge shall be regularly removed from the liquid adhesive reservoir.

170. Controls.

173. *Insert new paragraph to read:*

173. In systems installed in buildings equipped with automatic sprinklers or manual or automatic fire alarm systems, it is recommended that the necessary devices and connections be installed to automatically shut down the fans when the sprinkler or fire alarm systems operate.

190. Air Cooling and Heating Equipment.

The committee has voted to delete the entire text of rule 191 which covers the classification of refrigerants, and cover this entire subject by a reference to the Mechanical Refrigeration Safety Code. The committee has under consideration two different wordings. Adoption of this change will also require deleting the text of rule 192 in the previous edition and renumbering rule 193 as 192.

191. Mechanical refrigeration shall be installed in accordance with the American Standard Safety Code B-9 for Mechanical Refrigeration, latest edition.

191. The permissible use of specified refrigerants shall be determined for the various occupancies according to the classifications outlined in the American Standard Safety Code B-9 for Mechanical Refrigeration. It is further recommended that the details of refrigeration installations be made to comply with that general safety code.

Maintenance of Air Conditioning Systems

The following section on maintenance was also adopted:

Failure to maintain proper conditions of cleanliness in air duct systems and carelessness in connection with repair operations have been important contributing causes of several fires which have involved air conditioning systems.

The following recommendations apply, in general, to the period of operation of the system; systems operated only part of the year should be given a thorough general check-up before starting operation and again after shutting down.

1. Fresh Air Intakes.

(a) Conditions outside the fresh air intake should be examined at the time of inspection of the ducts. Items to be noted are, (1) Accumulations of combustible material near the intake, (2) Presence of buildings or structures which may present an exposure to the intake allowing smoke and fire to be drawn in, (3) Operating condition of any automatic damper designed to protect the opening against exposure fire.

(b) If accumulations of combustible material are noted, they should be immediately removed, and arrangements made to avoid such accumulations. Inspections should thereafter be made more frequently. If newly erected exposures are noticed, consideration should be given to the protection at the intake to see that it is adequate. (See Regulations, paragraph 136).

2. Inspection and Cleaning of Ducts.

(a) Inspections to determine the amount of dust and waste material in the ducts (both discharge and return) should be made quarterly, except that if after several inspections such frequent inspection is found unnecessary, the interval between inspections may be adjusted to suit the conditions.

(b) Cleaning should be undertaken whenever inspection indicates the need.

(c) Cooling and heating coils should be cleaned, if necessary, at the time of cleaning the ducts.

NOTE. Thorough cleaning of ducts may require scraping, brushing, or other positive means. Vacuum cleaning may not remove dust of an oily or sticky nature, or heavy accumulations in the elbows or seams. The amount and kind of dust and dirt will depend greatly on the occupancy and the arrangement of duct system.

3. Inspection and Cleaning of Plenum Chambers.

(a) Plenum chambers should be inspected monthly, except that if after several inspections such frequent inspection is found unnecessary, the interval between inspections may be adjusted to suit the conditions.

(b) Cleaning should be undertaken whenever inspection indicates the need. Where plenum chambers are found used for storage, arrangements should be made to prevent this, such as keeping the doors locked. (See Regulations, Rule 125.)

4. Filters.

(a) Unit filters should be renewed or cleaned when the resistance to air flow has increased to five times the original resistance or when it has reached a maximum of 0.5 inches, water gage, whichever is higher. A suitable draft gage should be provided for the purpose. Draft gages of a type which will operate a warning light or produce an audible signal when excessive dust loads have accumulated, are recommended.

(b) **Filters, intended to be thrown away, after use, should never be cleaned and re-used.**

(c) Care should be exercised in the use of liquid adhesives. Use of an adhesive of low flash point would create a serious hazard. (See Regulations, Rule 152.)

(d) Electrical equipment of automatic filters should be inspected monthly, observing the operation cycle to see that the motor, relays and other controls function as intended. Drive motors and gear reductions should be inspected at least semiannually, and lubricated when necessary.

5. Fans, Fan Motors and Controls.

(a) Fans and fan motors should be inspected at least quarterly, and cleaned and lubricated when necessary. Care should be exercised in lubricating fans to avoid allowing oil to run onto the fan blades. Fans should also be checked for alignment, and to see that they are running freely.

(b) Automatic fan controls should be examined at least once a year to see that they are in operable condition.

6. Fire Doors and Fire Dampers.

Each fire door and fire damper should be examined once a year, giving attention to hinges and other moving parts, to see that it is in good operable condition.

7. Repair Work.

Great caution should be exercised in the use of open flames or spark emitting devices inside of ducts or plenum chambers, or near air intakes. (See Regulations, Rule 114a.)

8. Inspection Form.

The use of an inspection form to assist in obtaining a thorough inspection is recommended. The form should be made up to fit the system or systems involved, listing the items needing attention.

AMERICAN SOCIETY *of* HEATING *and* VENTILATING ENGINEERS

Journal Section

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BULLETIN BOARD

On-to-Mackinac for the Great Lakes Summer Meeting, July 4-6, is the slogan for members to remember. For details of the Program consult p. 405.

* * *

Pres. J. F. McIntire addressed meetings of eleven chapters and several groups of members informally during March, April and May and reports a healthy interest in Society affairs and a rapidly growing membership.

* * *

E. K. Campbell, chairman of the Membership Committee, says, "I am very anxious that our membership work this year shall show sufficient results that there will be no net loss in the Society's income for the support of research work. Membership work is on a par in importance with research work. Research workers don't admit this, of course, but if we didn't have the membership, we wouldn't have the research work. Membership is necessary to support our other activities. It's up to every member to get a new member."

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KANSAS CITY: *Organized,* 1917. *Headquarters,* Kansas City, Mo. *Meets,* Second Monday in Month. *President,* A. L. Maillard, 3740 Washington St. *Secretary,* C. A. Flarsheim, P. O. Box 56.

MANITOBA: *Organized,* 1935. *Headquarters,* Winnipeg, Man. *Meets,* Fourth Thursday. *President,* William Worton, 508 Scott Bldg. *Secretary,* E. J. Argue, Ste. 11, Estelle Apts.

MASSACHUSETTS: *Organized,* 1912. *Headquarters,* Boston, Mass. *Meets,* Third Tuesday in Month. *President,* James Holt, Massachusetts Institute of Technology, Cambridge, Mass. *Secretary,* H. C. Moore, 69 Massachusetts Ave., Cambridge, Mass.

MICHIGAN: *Organized,* 1916. *Headquarters,* Detroit, Mich. *Meets,* First Monday after the 10th of the Month. *President,* W. C. Randall, 2250 E. Grand Blvd. *Secretary,* W. H. Old, 1761 Forest Ave., W.

WESTERN MICHIGAN: *Organized,* 1931. *Headquarters,* Grand Rapids, Mich. *Meets,* Second Monday in Month. *President,* C. R. McConner, 1904 Waite Ave., Kalamazoo, Mich. *Secretary,* W. G. Schlichting, 1417 W. Lovell St., Kalamazoo, Mich.

MINNESOTA: *Organized,* 1918. *Headquarters,* Minneapolis, Minn. *Meets,* Second Monday in Month. *President,* J. E. Swenson, 800 Hennepin Ave. *Secretary,* M. H. Bjerken, 4952-17th Ave., S.

MONTREAL: *Organized,* 1936. *Headquarters,* Montreal, Que. *Meets,* Third Monday. *President,* F. J. Friedman, 1221 Osborne St. *Secretary,* C. W. Johnson, 630 Dorchester St., W.

NEW YORK: *Organized,* 1911. *Headquarters,* New York, N. Y. *Meets,* Third Monday in month. *President,* O. O. Oakes, 119 Oakridge Ave., Summit, N. J. *Secretary,* T. W. Reynolds, 100 Pinecrest Dr., Hastings-on-Hudson, N. Y.

WESTERN NEW YORK: *Organized,* 1919. *Headquarters,* Buffalo, N. Y. *Meets,* Second Monday in Month. *President,* J. J. Landers, 701 Crosby Bldg. *Secretary,* W. R. Heath, 119 Wingate Ave.

NORTH CAROLINA: *Organized,* 1939. *Headquarters,* Durham, N. C. *President,* R. B. Rice, University of North Carolina, Raleigh, N. C. *Secretary,* T. C. Cooke, 400 E. Peabody St., Durham, N. C.

NORTHERN OHIO: *Organized,* 1916. *Headquarters,* Cleveland, O. *Meets,* Second Monday in Month. *President,* J. P. Jones, 448 Terminal Tower. *Secretary,* C. M. H. Kaercher, 3030 Euclid Ave.

OKLAHOMA: *Organized,* 1935. *Headquarters,* Oklahoma City, Okla. *Meets,* Second Monday. *President,* A. A. Hoppe, 213 W. First St. *Secretary,* S. L. Rolland, 321 N. Harvey Ave.

ONTARIO: *Organized,* 1922. *Headquarters,* Toronto, Ont. *Meets,* First Monday in Month. *President,* H. D. Henion, 1523 Davenport Rd. *Secretary,* H. R. Roth, 57 Bloor St., W.

PACIFIC NORTHWEST: *Organized,* 1928. *Headquarters,* Seattle, Wash. *Meets,* Second Tuesday in Month. *President,* R. O. Wesley, 334 Boren Ave., N. *Secretary,* H. T. Griffith, 324-1411 4th Ave. Bldg.

PHILADELPHIA: *Organized,* 1916. *Headquarters,* Philadelphia, Pa. *Meets,* Second Thursday in Month. *President,* R. F. Hunger, 220 South 16th St. *Secretary,* Edwin Elliot, 560 North 16th St.

PITTSBURGH: *Organized,* 1919. *Headquarters,* Pittsburgh, Pa. *Meets,* Second Monday in Month. *President,* R. A. Miller, 2200 Grant Bldg. *Secretary,* T. F. Rockwell, Carnegie Inst. Tech.

ST. LOUIS: *Organized,* 1918. *Headquarters,* St. Louis, Mo. *Meets.* First Tuesday in Month. *President,* R. J. Tenkonohy, 3650 Shaw Blvd. *Secretary,* C. F. Boester, 101 E. Essex, Kirkwood.

SOUTHERN CALIFORNIA: *Organized,* 1930. *Headquarters,* Los Angeles, Calif. *Meets,* Second Tuesday in Month. *President,* J. F. Park, 1234 S. Grand, Los Angeles, Calif. *Secretary,* E. P. Wells, 206 W. Shorb St., Alhambra, Calif.

NORTH TEXAS: *Organized,* 1938. *Headquarters,* Dallas, Tex. *Meets,* Second Monday in Month. *President,* C. L. Kribs, Jr., 4209 Shenandoah Ave. *Secretary,* L. S. Gilbert, 1314 Liberty Bank Bldg.

SOUTH TEXAS: *Organized,* 1938. *Headquarters,* College Station, Texas. *President,* R. F. Taylor, 911 Bankers Mortgage Bldg., Houston, Tex. *Secretary,* W. H. Badgett, Texas Engrg. Experiment Station, College Station, Tex.

WASHINGTON, D. C.: *Organized,* 1935. *Headquarters,* Washington, D. C. *Meets,* Second Wednesday in Month. *President,* T. H. Urdahl, 726 Jackson Pl., N. W. *Secretary,* P. H. Loughran, Jr., 4513—49th St.

WISCONSIN: *Organized,* 1922. *Headquarters,* Milwaukee, Wis. *Meets,* Third Monday in Month. *President,* D. W. Nelson, University of Wisconsin, Madison, Wis. *Secretary,* F. M. Hughey, 906 N. Fourth St., Milwaukee, Wis.

Air Conditioning Requirements of an Operating Room and Recovery Ward

By F. C. Houghten* (*MEMBER*) and W. Leigh Cook, Jr., M. D.,** Pittsburgh, Pa.

This paper is the result of research sponsored by the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS in cooperation with the Department of Industrial Hygiene, School of Medicine, University of Pittsburgh, Bindley Fund and the Elizabeth Steel Magee Hospital.

CONSIDERABLE interest has recently been shown in the application of air conditioning in hospitals, especially from a purely comfort point of view. Particular emphasis has been placed upon summer cooling and air conditioning in wards, private rooms, and various other hospital rooms. Temperature control for the air conditioned space is undoubtedly the most important factor, and it is natural that practices have followed closely those used in air conditioning of other places of assemblage.

More recently, there has been an intense interest in special applications of air conditioning to operating rooms, recovery rooms, and contagious wards. While the greater efficiency of the operating surgeon and his staff is an important consideration in such applications, of more interest has been the possibility of reducing spread of infection, arising either in connection with surgery or from contagious cases. This interest has received its major impetus from the re-opening of the question of air-borne infection by the recent work of Wells and others.[1-6] Previously for the past 10 or 15 years it had largely been the accepted opinion of the biologist and bacteriologist that the spread of infection resulting from bacteria-infected spray thrown from one person to the other by coughing and sneezing, could not and actually was not spread through the air for distances greater than a few feet.

However, the recent work of Wells has placed an entirely new complexion on this situation. His discovery that bacteria, including pathogenic organisms, can be and are carried through the air long distances and over long periods of time is perhaps today the subject of outstanding new interest in sanitation. As a consequence, the surgeon is actively considering the possibility that what has been accepted as an irreducible minimum of infections in surgical cases has actually been resulting from an entirely unsuspected source; namely, air-borne organisms. The older accepted theory that organisms, particularly pathogenic ones, were not normally carried through the air on dust particles, excepting where considerable air motion was set up, resulted in tightly closed and in most cases unventilated operating rooms. Windows were not opened for fear that drafts would stir up dusts. This school of thought was even carried in many cases to the point where a glass barrier was installed between the operating room and the conventionally sealed windows, in order to avoid small stray air currents and drafts coming through window cracks. This minimum introduction or change of air for ventilation resulted in two major problems: first, very high temperatures during the summer season, resulting from the high outside temperatures and accentuated by such other necessary sources of heat as steam and hot water baths and sterilizers; and second, attendant high concentration of volatile gases used in anesthesia, resulting from the elimination of all sources of air change or air ventilation. This latter condition has existed to such an extent that it has sometimes been said that a surgeon may cut from 10 to 15 years off his normal life expectancy due to continuous inhalation of relatively high concentrations of anesthetic.

These developments led to a consideration of the need of a thorough research investigation of the factors involved in and the desirability for the air conditioning of operating rooms and recovery wards. As a result, a program of investigation was initiated and some phases of it have since been accomplished.

While the possibilities for research were almost unlimited, a program was outlined for the purpose of indicating the most obvious direction of research investigation. These items will be further enlarged upon, including some details of the method of attack, particularly as pertains to the more physical aspects of the application of air conditioning. Item 5, dealing with the physiological and medical aspects, only covers the subject in a very general way and will naturally unfold and be developed as the work proceeds. The program includes a study of the items given:

1. *Feeling of Warmth:* Optimum temperature and humidity conditions within the operating room and recovery ward for the best interests of the patient, either directly, or through greater efficiency of the operating surgeon and his attendants.

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[1] Infection in Clean Operating Rooms, by F. L. Meleney. (*Surgery, Gynecology and Obstetrics*, 60:264; 1935.)

[2] Air-Borne Infection, by W. F. Wells and M. W. Wells. (*Journal of American Medical Association*, 107, 21:1698, Nov. 21, 1936.)

[3] Air-Borne Infection: Sanitary Control, by W. F. Wells and M. W. Wells. (*Journal of American Medical Association*, 107, 22:1805, Nov. 28, 1936.)

[4] Sterilization of Air in Operating Rooms by Special Bactericidal Radiant Energy, by D. Hart. (*Journal of Thoracic Surgery*, 6:45; 1936.)

[5] Ventilation and Atmospheric Pollution: A Bacteriological Method of Sanitary Air Analyses. (Report by Sub-Committee on Bacteriological Procedures in Air Analysis in Year Book, 1936-1937, Supplement to *American Journal of Public Health*, Vol. 27, No. 3, 1937.)

[6] Incidence of Air Borne Bacteria in Major Surgery of Multnomal County Hospital, by Nesbit and Brook. (*Surgery*, November, 1938.)

Presented at the 45th Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Pittsburgh, Pa., January, 1939.

2. *Bacteria:* The bacteria content of the atmosphere in an operating room as found in the past, and with the present air conditioning system; and further, how the bacteria content may be affected by ultra-violet sterilization and electrostatic precipitation of dust.

3. *Anesthetic Concentrations:* The relation between past performance without air conditioning and present performance with air conditioning and controlled ventilation, as affecting concentration of anesthetic at different points in the operating room.

4. *Static-Electric Sparks:* Relation between atmospheric conditions and the hazard of electrical sparking possibly causing ignition of air-gas mixtures.

5. *Physiological Aspects of the Subject:* Medical observations relative to weight, blood pressures, blood chemistries, and skin temperature; perspiration of attendants and patients; feeling of comfort, well-being, and presence or absence of fatigue of operators; urine chloride of patient before and after operation; bacteriologic content of operating room air without and with occupants, and effect on healing; and the effect of the recovery room as it aids or deters patient's recovery, which might be contrasted to a room in which no air conditioning exists.

The study indicated in Item 1 has been largely completed and will be discussed at length later in this report. However, this paper deals practically entirely with the engineering aspects of the study as related to the comfort and well-being of the operating surgeon and his attendants. The hospital and medical aspects of the problem will be presented in other publications.

The study of the bacteria content of the air, or Item 2 of the program, has been the subject of considerable difference of opinion. While some bacteria may not be harmful in other localities, as far as an operating room is concerned the presence of undesirable organisms may be considered as roughly proportional to the concentration of all such organisms. Therefore, an approved method of sampling air for bacteria content should be used to sample the air at various points in the operating room under different conditions, both as regards the use of the operating room itself, and the operation of the air conditioning system. Two general methods have been used for this purpose. The earlier procedure was to set sterile petri dishes at various points in the room and allow the bacteria and dust in the atmosphere to settle in them over a period of time and then to develop the bacteria collected. The second, more recent, and probably better method has been to centrifuge the air in a container, the inside of which is covered with an adhesive medium. This method of sampling is positive and quantitative, since a definite volume of air is centrifuged with the idea of getting all or at least a proportionate number of the living organisms out of the air tested. Such an instrument has been developed by W. F. Wells of the University of Pennsylvania.

As far as the percentage of bacteria in the air and their effect are concerned, it is recommended that a few tests under different atmospheric conditions and surrounding arrangements be made, such as without the air conditioning system in operation, with the system in operation including the electrostatic precipitator, and with all of this equipment and the ultra-violet sterilizer also in use. Undoubtedly, a wide variety of different tests should be made, as well as a considerable number of tests for each variation, in order to definitely establish the relation of bacteria content to such operations, the need of wearing masks, etc. Another study would be to determine the desirability of installing a glass barrier, between the operating room and the spectators' gallery, as affecting the bacteria content of the air.

After carefully considering these methods for studying bacteria, a very definite schedule should be set up, aimed to give the greatest amount of information with the least amount of study. The actual incubation of bacteria samples and method to be used thereby must necessarily be dictated by bacteriological experts. Up to date, relatively few observations have been made in connection with this phase of the study.

The concentration of anesthetic in the operating room, or Item 3 of the program, also should be given serious consideration. As mentioned previously, the life expectancy of surgeons is thought to be shortened an appreciable amount when exposed to high concentrations. Whether this is true or not, nevertheless high concentrations of anesthetic throughout a room are not a necessary consequence to the administering of anesthetic to a patient. Given a certain concentration as necessary at the mouth or nose, the concentration at points distant therefrom can be reduced to almost any desired value by the volume of air change. Of course, there must necessarily be some limitation in the amount of air change or ventilation which can be allowed without undesirable drafts, but it is probable that air change can lower the concentration of anesthetic in the operating room to levels far below those found in usual practice, where no special consideration has been given.

One important phase of the study should therefore be the sampling of air at various points in the room with reference to the source of distribution of anesthetic to the atmosphere, in order to determine the concentration with different rates of air change or different operations of the air conditioning system. The sampling of air is well established by gas chemistry, and analyses for the more common anesthetics used are also available in most instances.

Item 4 of the program, or the relation between atmospheric conditions and the hazard of electrical sparking, and thereby ignition of air-gas mixtures, seems to be of some significance, but to what extent it is important is better known by the operating surgeon and others. Before a study is to be made of this subject, careful analysis should be made first of the available literature on the relation between static electrical sparks and atmospheric conditions in other industries, such as the textile industry. Any future planning of this phase of the subject will have to be developed after due consideration to its importance.

Description of Equipment

An operating room and recovery ward at the Magee Hospital, each having a northern exposure on the fourth floor, were chosen for the study and were remodeled in a number of respects, including the installation of an air conditioning system for the rooms. The air conditioning system installed was designed by a committee of doctors and air conditioning engineers, not with a view of fulfilling a predetermined opinion of what air conditioning should apply, but with a view of making available an experimental system which could be operated so as to supply a wide range of atmospheric conditions for experimental purposes.

The layout of the operating room, recovery ward, and air conditioning system is shown in Fig. 1. Outside air is brought in at *A* through a duct containing a preheater, a cloth air filter, and an electrical precipitator. The duct then branches, and part of the air is drawn through an air washer and reheater by a fan, which discharges this air through a duct system to 6 outlets located in the ceiling of the operating room. The second portion of the air, which may be mixed with recirculated air from the recovery ward, is drawn over cooling coils and a reheater by a second fan, which then delivers this air to a duct system leading to two outlets in the ceiling of the recovery ward. The system is designed to supply 1200 cfm to the operating room and a similar amount, including up to 50 per cent recirculated air, to the recovery ward.

A 10-ton dichlorodifluoromethane compressor applies refrigeration to water by means of a shell-and-tube exchanger. A system of storage tanks, pumps, and thermostatic controls circulates this water through the washer, thus providing cooling and humidity control for the operating room, and also through the cooling coils, thus supplying cooling and dehumidification for the recovery ward. This system therefore allows easy control over both the temperature and dew-point of the air supplied to the operating room, as well as the temperature and, to a lesser extent, the moisture content of the air in the recovery ward.

The operating room is 15 by 32 ft, including a spectators' gallery having a seating capacity for 30 persons. The four operating room windows, with two radiators located under them, are shielded from the rest of the operating room by a glass enclosure. Originally in laying out the system, provision was made for exhausting the air through this space so as to decrease the cooling load from the exposed windows. However, this distribution of the vitiated air from the operating room was not used, for it was soon learned by other attendants in this wing of the fourth floor that the discharged air from the operating room had sufficient residual cooling capacity to add considerable comfort cooling to the rest of the hospital wing when it was discharged into the corridor.

As a part of the experimental equipment in the operating room, an ultra-violet sterilamp is installed directly over the operating table. The recovery ward has a capacity of 7 beds, and has been used solely as a post-operative room.

The experimental equipment was installed and put into operation during June, 1938; and the operating room and recovery ward have since been used continuously, an average of 23 operations being performed there weekly. A resident physician having a few other duties was assigned to the operation of the equipment and collection of the necessary data in connection with the use of the air conditioning equipment for the operating room and recovery ward.

A previous report[7] has recommended that a relative humidity between 50 and 60 per cent be maintained in an operating room, in order to eliminate explosion haz-

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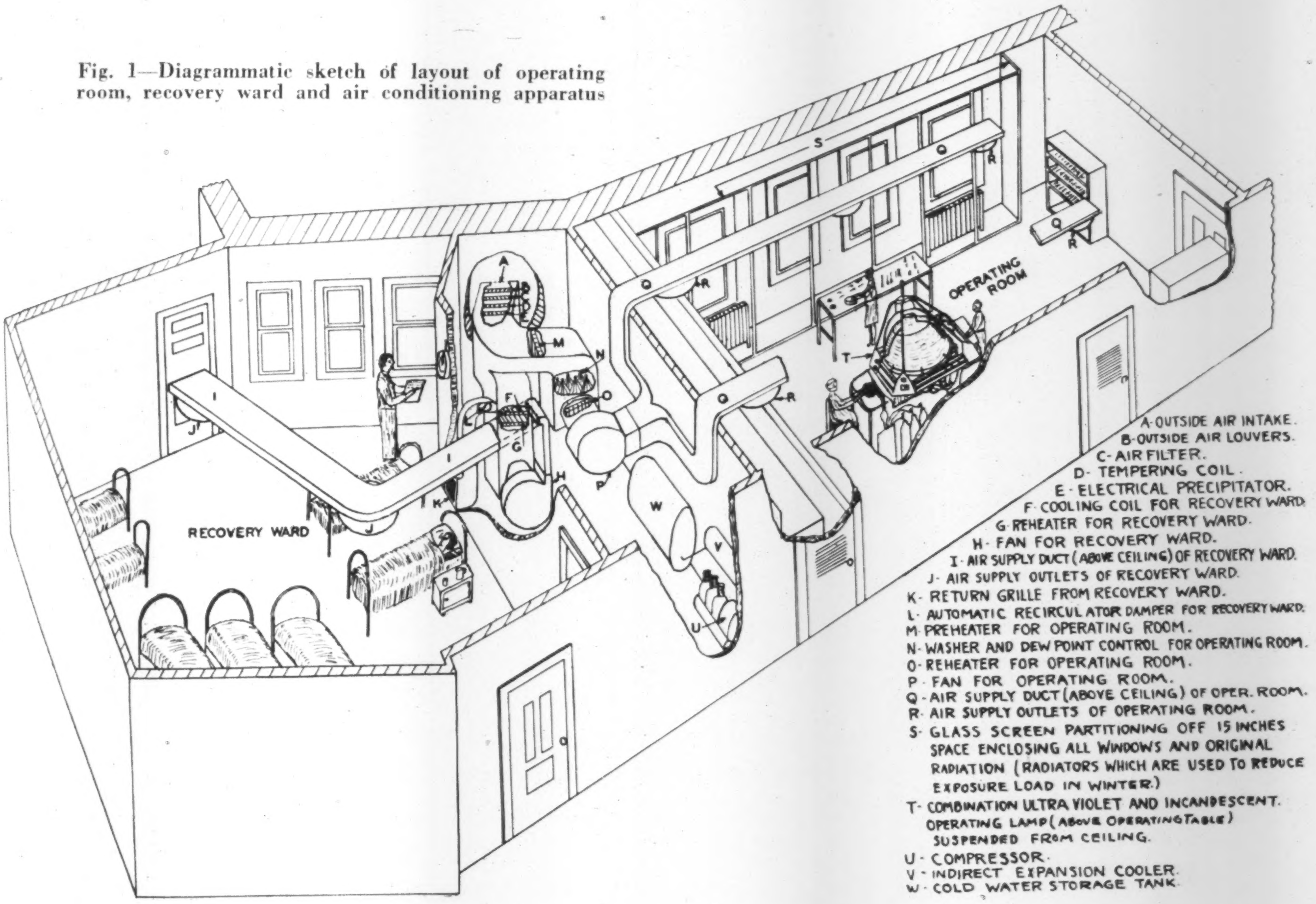
[7] Report of Committee on Anaesthesia. (*Journal of American Medical Association*, May 10, 1930.)

Fig. 1—Diagrammatic sketch of layout of operating room, recovery ward and air conditioning apparatus


RECOVERY WARD
OPERATING ROOM
A
F
G
H
I
J
K
M
N
O
P
Q
R
S
T
U
V
W
A- OUTSIDE AIR INTAKE.
B- OUTSIDE AIR LOUVERS.
C- AIR FILTER.
D- TEMPERING COIL.
E- ELECTRICAL PRECIPITATOR.
F- COOLING COIL FOR RECOVERY WARD.
G- REHEATER FOR RECOVERY WARD.
H- FAN FOR RECOVERY WARD.
I- AIR SUPPLY DUCT (ABOVE CEILING) OF RECOVERY WARD.
J- AIR SUPPLY OUTLETS OF RECOVERY WARD.
K- RETURN GRILLE FROM RECOVERY WARD.
L- AUTOMATIC RECIRCULATOR DAMPER FOR RECOVERY WARD.
M- PREHEATER FOR OPERATING ROOM.
N- WASHER AND DEW POINT CONTROL FOR OPERATING ROOM.
O- REHEATER FOR OPERATING ROOM.
P- FAN FOR OPERATING ROOM.
Q- AIR SUPPLY DUCT (ABOVE CEILING) OF OPER. ROOM.
R- AIR SUPPLY OUTLETS OF OPERATING ROOM.
S- GLASS SCREEN PARTITIONING OFF 15 INCHES SPACE ENCLOSING ALL WINDOWS AND ORIGINAL RADIATION (RADIATORS WHICH ARE USED TO REDUCE EXPOSURE LOAD IN WINTER.)
T- COMBINATION ULTRA VIOLET AND INCANDESCENT. OPERATING LAMP (ABOVE OPERATING TABLE) SUSPENDED FROM CEILING.
U- COMPRESSOR.
V- INDIRECT EXPANSION COOLER.
W- COLD WATER STORAGE TANK.

ards arising from static electricity. In accordance with this recommendation, all tests in the present study were conducted with various effective temperatures, but all at a relative humidity of approximately 50 per cent.

The study so far has been confined largely to Item 1 of the research program outlined, and the research results contained in this paper are limited largely to this phase of the study.

Experimental Observations

Coincidental data taken included the types of work done in the operating room, the subsequent course of the patient in the hospital, and the general reactions of both patient and surgeon toward the equipment in use. An attempt was made throughout to be as purely objective as possible in the gathering of facts and in questions asked. At the outset there was such a general enthusiasm among the operating personnel concerning the cooled space and a willingness to perform elective surgery in the heat of summer, because of the standard conditions which could be maintained for the benefit of the patient, that an abundance of facts confronted the tabulator. Numerous consultations determined the type of information which should be gathered in an effort to have a uniform picture of the work throughout its entirety.

The following problems were suggested for solution concerning the patient's course in the hospital:

1. Do patients who are subjected to a standard avertin, gas, or ether anesthesia develop post-operative pulmonary complications less or in greater percentage when taken directly from the operating room to the air conditioned recovery ward?
2. Do such patients, in a room with 12 air changes per hour, react from anesthesias more quickly than those in humid, sultry wards with little air change and circulation?
3. Is there any perceptible difference in post-operative temperature, pulse, and respiration comparing those kept at a constant condition of approximately 75 F dry-bulb and 40 to 50 per cent relative humidity, and those control cases in the warmer unconditioned wards?
4. Determine the amount of post-operative perspiration, liquid intake, and urinary output in an effort to objectively ascertain the benefit to the patient of being in an ideal post-operative atmosphere.
5. Obtain reactions from both patients and attending physicians as to the advantages or disadvantages of air conditioned recovery wards during the summer months.

During the test months of July, August, and September, 123 patients of the total number operated upon during the summer were placed in the air conditioned recovery ward. Of these, 88 had been operated upon in the air conditioned operating room, and the other 35 had been in ordinary operating rooms. These cases included 36 laporotomies (an operation in which the abdomen is opened), 20 vaginal operations, 48 combined vaginal and abdominal operations, 12 other surgical procedures, and 7 obstetrical cases mostly Caesarean sections. The 123 surgical operations mentioned covered the ordinary types of surgical procedures in a general hospital. The length of stay in the air conditioned recovery ward varied depending upon the need for beds and the general post-operative condition of the patient, the average time being 80 hours and the longest being 9 days.

Throughout the past summer there were but three post-operative complications. One patient died post-operatively of a kidney complication, the patient being 62 years old and a bad operative risk. Another died 6 days after a Caesarean section, the cause being peritonitis. A third patient developed a lung abscess post-operatively which was believed secondary to an embolus. However, none of these 123 cases developed post-operative pulmonary complications. Taking charts from a similar period during the year 1937 it was found that there had been a total of 4 post-operative complications including one death, one case in which the operation reactivated an old tuberculosis, and two cases of post-operative atelectasis (collapse of lung), both of which recovered, but were definitely classified as post-operative pulmonary complications.

Comparing the charts of those 123 patients in the air conditioned recovery ward and those others returned to private rooms and the regular surgical wards, no conclusions can be reached as to the advantage of the controlled air condition and air change in reducing the total time required for the patient to react from anesthesia. Because of the rather general use at the Magee Hospital of rectal anesthesia avertin, which is not eliminated through the respiratory tract, it is difficult to determine whether proper air conditioning in the recovery ward is of advantage in reducing anesthesia concentration in the lungs. Pulse and respiration records of patients in the recovery ward and control cases had such wide variations that it would be unable to draw any satisfactory conclusions as to the advantages of the recovery ward post-operatively in these respects, unless a large amount of additional data were to be obtained. The individual reaction of patients to operations and the varying degrees of shock produced by surgical procedures, probably account somewhat for the inability to show any objective advantage of an air conditioned recovery ward.

From a medical standpoint there was some debate as to the advisability of subjecting an anesthetized patient, to even the slight ranges of heat and cold used in collecting the data for this paper. This feeling was founded on the statements of Barber and Bourne[8] regarding ether anesthesia on dogs, and the generally accepted but hardly proven theory that anesthesia causes the subject to lose heat control regulation. Rectal temperatures were taken throughout laparotomies of duration of 1 to 1½ hours to see the effect of avertin, gas, or ether anesthesia on the body temperature. Five recordings were made during the operations for chronic pelvic complaints, not associated with pyrexia, and two pre-operative control recordings were made for periods of 2 hours at a time. In no case was there a variation of rectal temperature of more than ⅘ F. Three of these recordings were made in a room conditioned to a temperature of 75 F and a humidity of 50 to 55 per cent, and the others were in rooms well over 80 F with varying humidity, not conditioned. It was therefore thought that with the patient properly draped he could be kept at a safe body temperature even though the conditions of the room were varied.

A careful record of liquid intake and output, which was done in an attempt to evaluate roughly the loss of fluid from the skin and respiratory tract, was made on those patients in the air conditioned recovery ward and controlled cases throughout the hospital. It was thought that the patients in the recovery ward would have a higher urine output in comparison to liquid intake than those in the warmer parts of the hospital, thereby proving less post-operative perspiration. Such, however, was not the case, the variations of intake and output being as great in the air conditioned recovery ward as with the controlled cases. However, mention in the nurses' notes was made by those working in both conditioned and non-conditioned wards that there was much less need to change gowns post-operatively on those cases kept in an ideal post-operative condition, and that there was much less restlessness on the part of the patient in these conditions.

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[8] The Influence of Ether in Dogs, by H. G. Barber and W. Bourne. (*American Journal of Physiology*, 67:399, 1924.)

Numerous operations which would likely be delayed until cooler weather were performed throughout the summer by the surgical staff. The advantages of the air conditioned operating room and recovery ward in lessening the possibility of post-operative heat prostration in the extremes of summer heat undoubtedly influenced their decisions.[9] Operations on the thyroid gland which are more hazardous in the summer time were performed with very little if any apprehension on the part of the staff, and no post-operative thyroid crises resulted during this period.

Throughout the summer, patients continually remarked about the difference in their general feeling of well-being in the air conditioned recovery ward as compared with that on transfer to the unconditioned part of the hospital, even though they were nearer full recovery from their operation when transferred. Other patients who had had previous operations remarked that they had never been so comfortable post-operatively; naturally many were miserable enough to be entirely ignorant of their ideal surroundings.

Also, numerous comments from the medical staff about the air conditioned operating room were heard throughout the summer. These remarks were to the effect that following a whole morning spent in an operating room the surgeon felt he could go to his office with a freshness never before experienced during the hot summer months. Many felt that the air conditioned operating room was far superior to the ordinary operating rooms regarding comfort, freedom of perspiration and lack of fatigue. The fact that members of the surgeon's family and his patient noticed to a much less extent the odor of anesthesia on the surgeon's breath after a morning in the air conditioned operating room was also mentioned by some of the staff.

Comfort Reactions

Data were collected throughout the summer months on Item 1 of the original program, or the study of optimum conditions of effective temperature for the comfort of the surgeon and those in attendance. With the necessary modifications dictated by the normal operation of the hospital, the study was directed along lines similar to those used by the ASHVE Research Laboratory in earlier comfort studies,[10, 11, 12, 13]. On a given day, a predetermined atmospheric condition, as determined by the relative humidity and effective temperature, was maintained. On convenient occasions an observer interrogated the operating surgeon and his attendants, including internes and nurses, concerning their feeling of warmth, degree of sensible perspiration, and general reactions toward the atmospheric conditions. A feeling of warmth was graded according to an arbitrary index previously used by the Laboratory, in which ideal comfort is given an index rating of "4," feelings of slightly cool and slightly warm "3" and "5," respectively, and decidedly cool and decidedly warm for comfort "2" and "6," respectively. The additional two indices used in some of the earlier studies, namely, "1" for decidedly cold and "7" for decidedly hot, were not included, since it was deemed undesirable and also unnecessary to subject attendants or patients to these extremes. In all, 348 opinions of feelings of warmth were obtained from doctors, nurses and internes during the summer test period, and a somewhat lesser number of observations concerning the absence or degree of sensible perspiration. All of these individual observations are plotted against the effective temperature of the atmospheric condition in Fig. 2.

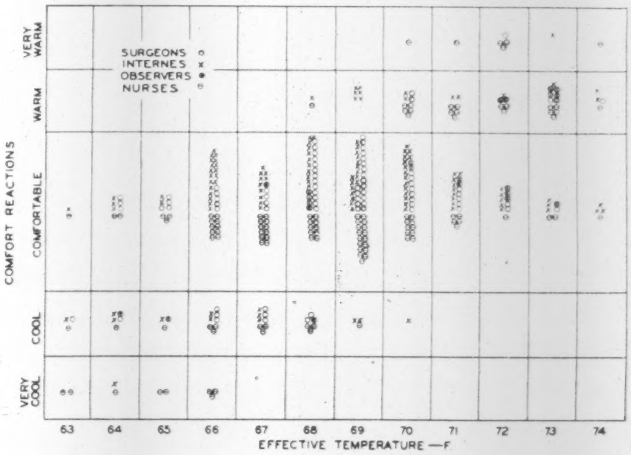

Fig. 2—Relation between the effective temperature of the air condition maintained in the operating room and the number of surgeons, internes, observers and nurses feeling comfortable, slightly cool, slightly warm, very cool and very warm

This gives a plot characteristic quite similar to identical plots obtained from earlier Laboratory studies for normal occupants of an assembly room. The great preponderance of number of observations of comfort appears in the center portion of the chart with decreasing numbers of observations to the right and left. Feelings of slightly cool "3" and slightly warm "5" are found, respectively, more or less to the left and to the right of the center, while still farther to the left and to the right are scattered observations of too cool "2" and too warm

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[9] Post Operative Heat Stroke, by Moschowitz. (*Surgery, Gynecology and Obstetrics;* October, 1916.)

[10] Determination of the Comfort Zone, by F. C. Houghten and C. P. Yagloglou. (ASHVE TRANSACTIONS, Vol. 29, 1923, p. 361.)

[11] Comfort Standards for Summer Air Conditioning, by F. C. Houghten and Carl Gutberlet. (ASHVE TRANSACTIONS, Vol. 42, 1936, p. 215.)

[12] Cooling Requirements for Summer Comfort Air Conditioning, by F. C. Houghten, F. E. Giesecke, C. Tasker and Carl Gutberlet. (ASHVE JOURNAL SECTION, *Heating, Piping and Air Conditioning,* December, 1936, p. 681.)

[13] Summer Cooling Requirements of 275 Workers in an Air Conditioned Office, by A. B. Newton, F. C. Houghten, Carl Gutberlet and R. W. Qualley. (ASHVE JOURNAL SECTION, *Heating, Piping and Air Conditioning,* December, 1937, p. 758.)

"6." From this chart a temperature range somewhere around 67 to 70 deg ET would readily be selected as including the most desirable conditions. However, the fewer observations obtained at higher and lower temperatures somewhat mask the general effect of the concentration of the data.

Separate symbols are used in Fig. 2 to indicate doctors, internes and nurses. While no doubt there is some difference in the temperature at which each group is comfortable, there were not sufficient individual observations made during the brief study to conclusively demonstrate this difference. However, the segregation of the data for the three groups tends to show that surgeons and internes both indicated maximum comfort at about 68 deg ET, while the nurses indicated maximum comfort at a little above 69 deg ET.

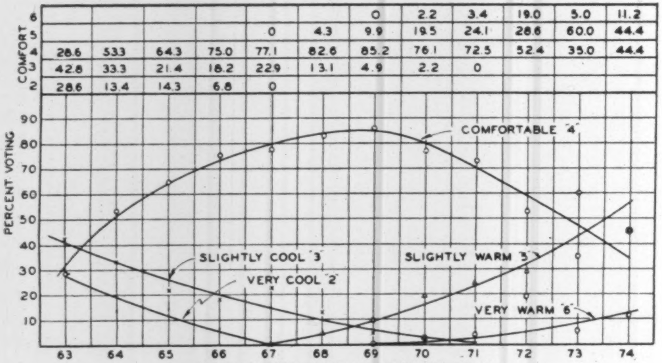

Fig. 3—Relation between the effective temperature of the air condition maintained in the operating room and the percentage of its occupants voting comfortable, slightly cool, slightly warm, very cool and very warm

Fig. 3 gives a better numerical picture of the true relationship between the comfort indices and the effective temperature of the atmospheric condition. In this figure the percentage of observations expressed by the 5 indices, rather than their actual number, are plotted against effective temperature. Index "4," or ideal comfort, gives a parabolic type of curve, showing a minimum number feeling *ideal comfort* at about 62 deg ET. This curve then rises to a maximum of about 85 per cent feeling *ideal comfort* between the effective temperatures of 68 and 69 deg. With additional rise in effective temperature the curve falls until only 35 per cent are comfortable at an effective temperature of 74 deg. This curve is characteristic of all those obtained by the Laboratory in similar earlier studies. The fact that the curve is more steep on the cool side than on the warm side indicates that surgeons and attendants in an operating room, like persons in any type of audience hall, more readily sense discomfort due to a given number of degrees rise in temperature from that giving optimum comfort. The curve is characteristic also in that 100 per cent comfort is never found for any given condition; even when more than 80 per cent of all individuals indicated a feeling of *ideal comfort,* there were always some who felt either too warm or too cool.

The slightly cool "3" and decidedly cool "2," and the slightly warm "5" and decidedly warm "6" percentage curves are also characteristic. The slightly cool and slightly warm rise more rapidly on either side of the condition for ideal comfort; while the decidedly cool and decidedly warm rise first slowly and then more rapidly, with wider variations in air conditions on the cool and warm side.

The parabolic curve of percentages indicating comfort in Fig. 3 is somewhat broader than those found in most other Laboratory studies for seated occupants in places of assemblage. This is probably due to the somewhat varying intensity of activity of those in attendance at operations. Undoubtedly in a major operation the surgeon and his more responsible attendants exert a greater energy, resulting in comfort and higher rates of metabolism at lower temperatures. This accounts not only for the somewhat greater spread of curve but also in part for the slightly lower effective temperature than usually found at which the maximum percentage of workers feels comfortable. The increase in the clothing worn, particularly the masks covering parts of the head and face, and radiant heat resulting from intense illumination, and the close proximity of the workers to each other should also serve to account for comfort at the lower temperature. The point between 68 and 69 deg ET at which the doctors and their attendants were more often comfortable is significantly lower than the 70 to 73 deg ET, with an average of about 72 deg, that was obtained for seated occupants in a summer cooled room as found in earlier Laboratory studies. The slightly higher temperature at which the nurses were comfortable is in agreement with earlier findings which show that for persons seated at rest in a comfortable room, women desire a temperature of from 1 to 2 deg higher than men.

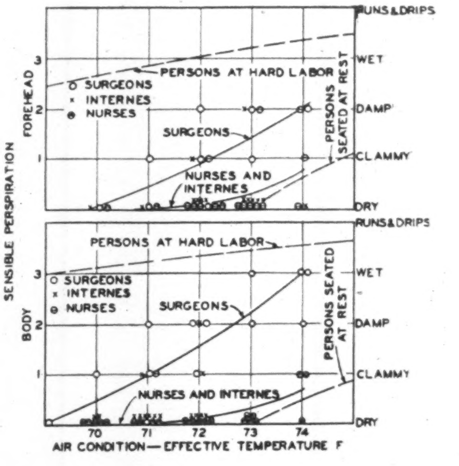

Fig. 4—Sensible perspiration on body and forehead of surgeons, internes and nurses while participating in operations with air conditions in the operating room at indicated effective temperatures and relative humidity of approximately 50 per cent. Broken line curves from other Laboratory studies for persons seated at rest and persons at hard labor in atmospheres at the indicated effective temperatures and a wide range of relative humidity shown for comparison

The sensible perspiration curves in Fig. 4 are drawn for both body and forehead perspiration of the surgeon, internes, and nurses, while participating in operations with air conditions in the operating room at the indicated effective temperatures and relative humidities in the neighborhood of 50 per cent. An arbitrary index for sensible perspiration, as used in previous studies at the Laboratory, was used in this present hospital study. An index rating of "0" is given to a dry condition of the skin, "1" for clammy, "2" for damp, "3" for wet, and "4" for the condition when the perspiration runs and drips down the surface of the skin. As mentioned previously, it was thought undesirable and also unnecessary to subject the patients and their attendants to extreme atmospheric conditions; hence, no votes were obtained for the "4" perspiration index.

As would be expected, the curves for the surgeons for both body and forehead perspiration are higher than the corresponding ones for the nurses and internes, this being due most likely to the greater activity and mental strain of the surgeons during the performance of the operation. Also, agreement with former studies is noted in the fact that the curves for body perspiration are located slightly higher than the corresponding curves for forehead perspiration.

For comparison, the broken line curves from former laboratory studies for persons seated at rest and persons at hard labor are superimposed on Fig. 4. Whereas the curves for the present hospital study were obtained in tests made at the indicated effective temperatures with a relative humidity of approximately 50 per cent maintained throughout, the curves from the former studies are the averages for a wider range of relative humidities. Nevertheless, this figure serves quite well to indicate the relative position of the hospital curves in comparison with the former studies. It must be kept in mind, however, that the hospital curves, especially those for the surgeons, are located by means of a relatively few points. Further study will serve to locate these curves more accurately.

Acknowledgment

The authors highly appreciate the valued cooperation of Miss J. J. Turnbull, Superintendent of the Magee Hospital, Dr. W. S. McEllroy, Acting Dean of the School of Medicine of the University of Pittsburgh, and Dr. T. L. Hazlett, Head of the Department of Industrial Hygiene of the School of Medicine of the University of Pittsburgh, their cooperation having been necessary for the success of the study. Appreciation is extended also to the Magee Hospital Board, who made the necessary space available and assumed a considerable portion of the cost of remodeling the rooms and installing the air conditioning equipment.

The authors acknowledge their indebtedness to Doctors C. J. Barone, B. Z. Cashman, M. B. Ferderber, A. W. Sherrill, and J. W. Shirer, as well as the rest of the surgical staff, for their valued medical advice and suggestions, and to Prof. C. M. Humphreys, G. S. McEllroy and H. W. Reding, who aided in the design and installation of the experimental air conditioning system.

Acknowledgment is given also to the kind cooperation of the hospital management, including the engineering staff, for maintaining the conditions required for the tests, and the surgeons and their attendant staffs using the operating room for their cooperation, at times under trying circumstances, in aiding in the collection of the data on which this paper is based.

Pittsburgh Chapter Discusses Proposed Code

April 10, 1939. Pres. R. A. Miller called the Pittsburgh Chapter meeting to order in the private dining room of Stouffer's Restaurant at 7:40 p. m. Thirty-five members and guests attended.

L. S. Maehling, treasurer, read his report and J. F. S. Collins, Jr., general chairman for the 1939 Annual Meeting, stated that a few minor items remained to be settled and that the final report was not complete.

The chairman read a report from the Attendance Committee recommending certain changes in meeting procedure.

President Miller introduced Don Maré, local director, Dale Carnegie Institute, as the after-dinner speaker. Mr. Maré's subject was Presenting Engineering Reports in a Colorful Manner and in a short talk of 15 min he outlined several methods by which engineering reports could be reduced to non-technical language for the lay audience.

After President Miller outlined a suggested method of procedure, the report of the committee appointed to study the proposed National Board of Fire Underwriters Code was presented to the Chapter for discussion. As several members desired more time to study the report before voting on it, it was moved by P. C. Strauch, seconded by E. H. Riesmeyer, Jr., and passed that a discussion of the report proceed as scheduled but that action be deferred until a later date.

President Miller then directed the chairman of the committee to read the report, having committee members make such comment as deemed necessary to amplify the committee's findings.

It was moved by E. S. Scanlon, seconded by R. J. J. Tennant, and passed that the code report be submitted to the Chapter membership accompanied by mail ballot upon which members could express their approval or disapproval and return the ballots to Secy. T. F. Rockwell on or before April 24.

It was moved by Mr. Scanlon, seconded by Mr. Tennant, and passed that the Committee's report be considered as adopted as read unless a majority of the Chapter membership returns ballots disapproving the report.

St. Louis Chapter Meets with Engineers Club

April 6, 1939. A dinner at the Kingsway Hotel preceded the business meeting at which 30 members and guests of St. Louis Chapter were present, with Dr. C. A. Mills, Cincinnati, as guest of honor.

Pres. E. E. Carlson called the meeting to order at 6:45 p. m. and asked for reports from standing committees.

C. E. Hartwein reported on the progress of plans for the annual dinner dance.

G. W. F. Myers, chairman of the Nominating Committee, submitted the names for prospective officers for the year 1939-40 as listed in the report of the May 2 meeting. Other members of the Nominating Committee were Paul Sodemann, R. C. Driemeyer, J. H. Carter and J. M. Foster. It was moved by Mr. Boester and seconded by E. A. White that the nominations be accepted.

The meeting was then adjourned at the Kingsway and continued at the Engineers Club as a joint meeting with their members and the attendance was approximately 200.

J. G. Rosebrough, Jr., president of the Engineers Club, turned the meeting over to Mr. Carlson, who introduced Dr. Mills, professor of experimental medicine, University of Cincinnati.

Dr. Mills' talk was very interesting and well presented as evidenced by the number of questions, according to the report of Secretary Fagin.

Mr. Rosebrough closed the meeting with a rising vote of thanks to Dr. Mills.

Air Filter Performance as Affected by Low Rate of Dust Feed, Various Types of Carbon, and Dust Particle Size and Density

By **Frank B. Rowley* and Richard C. Jordan**** (*MEMBERS*), **Minneapolis, Minn.**

This paper is the result of research sponsored by the American Society of Heating and Ventilating Engineers in cooperation with the Engineering Experiment Station, University of Minnesota

THIS paper presents the results of a research program which is a continuation of the work described in a previous paper[1] presented at the Semi-Annual Meeting of the Society, June, 1938.

The object of this part of the program was to determine the dust arrestance for low rates of dust feed through the filter, and filter performance when using different types of carbons, dusts of different particle sizes, and dusts of different densities. The test apparatus and procedure were described in the previous paper. The apparatus, with the exception of the dust feeding device, was the same as that described in the ASHVE Standard Code for Testing and Rating Air Cleaning Devices Used in General Ventilation Work. The photograph, Fig. 1, shows a general view of the test equipment as set up and used throughout the tests.

As in the previous test program four filters were selected as typical of those used in practice, and were used throughout all of the tests. These filters have been designated by the letters *A*, *B*-1, *C*, and *D* and were described in detail in the previous paper. Briefly they may be described as follows:

A—A permanent type of cleanable oil filter, 4 in. thick, with 24 layers of expanded metal and wire screen graded from coarse mesh at entrance to fine mesh at leaving side.

B-1—A viscous coated throw-away type filter 2 in. thick. The fibrous media were graded in fiber size, density, and oiling from entering to leaving side. This filter is designated in this report as *B*-1 due to the fact that slight changes had been made in the oiling and fiber diameter from those filters used in the previous report. These changes, however, did not appear to make any appreciable difference in the test results.

C—A cellular type filter 2 in. thick. The filter was built in two sections each with the axis of cells set at 45 deg to the center line of duct and at 90 deg to each other. The cells on the entering side were of larger dimension than those on the leaving side of the filter.

D—A filter of cotton media of coarse material on the entering side and glazed on the leaving side. The filter media were accordion plaited in frame to give an area of approximately 12 times the cross-sectional area of air stream.

For convenience the results given in this paper have been grouped under six headings as follows:

1. Rate of Dust Feed and Filter Arrestance.

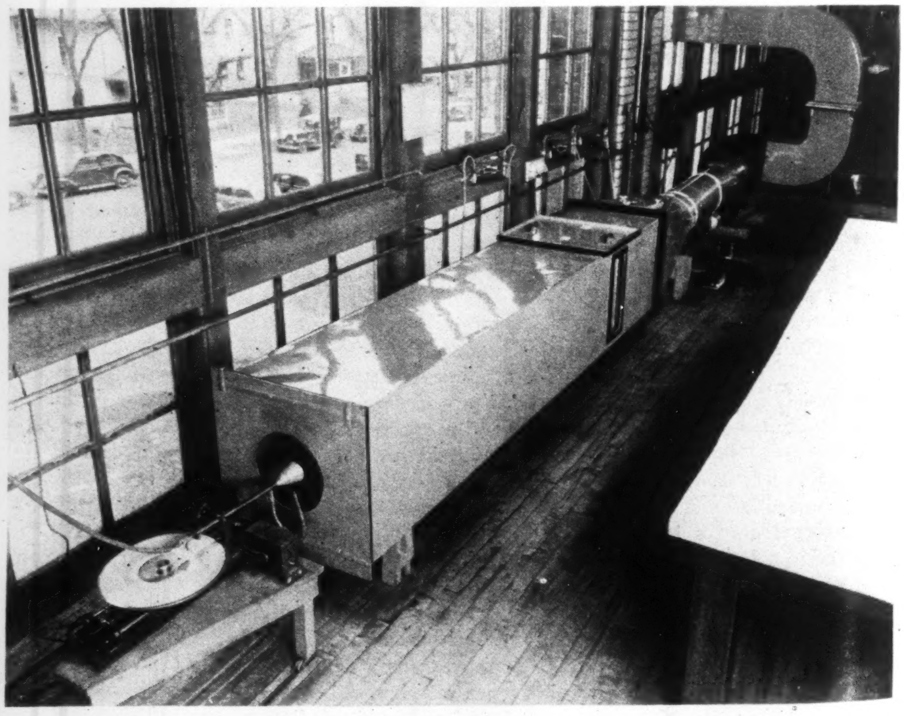

Fig. 1—Assembled view of test apparatus

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*Director Engineering Experiment Station, University of Minnesota.

**Instructor, Engineering Experiment Station, University of Minnesota.

[1] Air Filter Performance as Affected by Kind of Dust, Rate of Dust Feed and Air Velocity Through Filter, by Frank B. Rowley and Richard C. Jordan. (ASHVE Journal Section, *Heating, Piping and Air Conditioning*, Aug., 1938. p. 539.)

Presented at the 45th Annual Meeting of the American Society of Heating and Ventilating Engineers, Pittsburgh, Pa., January, 1939.

2. Dust Particle Size and Filter Performance.
3. Different Types of Carbon and Filter Performance.
4. Dust Density and Filter Performance.
5. General Comparisons of Filter Characteristics.
6. Conclusions and Recommendations.

Rate of Dust Feed and Filter Arrestance

The standard test code for rating air filters calls for 0.35 g (grams) of dust per 1000 cu ft of air. This corresponds to a rate of 17.7 g per hour when using a 20-in. square filter with a face air velocity of 300 fpm. In the first series of tests the rate of dust feed was raised to 20 g per hour for a 20-in. filter with 300 ft face velocity to provide a practical rate of feed to meet the code requirements. When the test results for this rate of dust feed were compared to those for rates of 40 and 60 g per hour, other conditions remaining the same, it appeared that much higher rates of feed might be justified in the standard code.

The lowest rate of dust feed used in the first series of tests was 10 g per hour, and the question arose as to whether the filter performance at high rates of dust feed, selected for test purposes, would be comparable to the performance characteristics which might be expected on the filter at the very low rates of feed met in practice. In order to answer this question a series of tests was run in which all filters were tested at a dust feed of 2 g per hour, other conditions remaining constant and equal to former tests. The dust mixture for this series consisted of 50 per cent Pocahontas ash screened through 200-mesh screen, 20 per cent Illinois fly-ash passing a 200-mesh screen, 20 per cent Germantown Eagle Brand lampblack passing a 100-mesh screen, and 10 per cent Fuller's Earth passing a 100-mesh screen. The results of this series of tests together with the previous tests ranging from 10 to 100 g per hour of the same dust mixture are shown in Table 1. The corrected test values shown under the 2 g rate take into consideration the weight of dust in the laboratory air. To obtain the additional weight the test apparatus was run without a filter in place and with no artificial dust feed. The increase in crucible weight was recorded for four 5-hour periods. The recorded increases were 0.0015, 0.0013, 0.0017, and 0.0015, giving an average of 0.0015 g for the 5-hour period. As a check on this method, a filter, which from previous tests was estimated to have an arrestance of 80 per cent, was placed in the test apparatus and a test run was made also without the addition of the dust mixture to the air stream. The gain in crucible weight was found to be 20 per cent of that without the filter, indicating that the calibration tests were correct, and that the weight of dust in the laboratory air used for the filter tests increased the dust fed to the filter by approximately 0.248 g per hour. This correction was made for the 2-g rate, but not for the higher rates shown in Table 1. This correction obviously would have much less effect for the higher rates of dust feed.

Table 1—Average Dust Arrestances for Filters *A*, *B*, *C* and *D*
(*Face air velocity* 300 *fpm*. *Dust mixture* 50, 20, 20, 10)

Filter	Rate of Dust Feed, Grams per Hour						
	2	10	20	30	40	60	100
A	77.5 (Corrected 80.1)	—	77.2	—	77.5 80.3	76.9	79.7
B	82.1 (Corrected 84.3)	80.0	78.2	81.3	81.0 81.9 81.7	82.0	82.8
C	71.6 (Corrected 75.2)	72.3	72.0	—	69.9	71.4	68.2
D	88.4 (Corrected 90.7)	89.8	92.5 92.0	—	93.5	94.6	92.4

Table 2—Particle Size Distribution in Different Kinds of Dusts

Type of Dust		Approx. Avg. Diam. of Particle	Approx. Diam. of Particle with Avg. Volume	Particle Count Distribution			Per Cent Vol. with Diam. More Than 25 Microns
Material	Screen Mesh			Per Cent Less Than 5 Micron	Per Cent Less Than 15 Micron	Per Cent Less Than 25 Micron	
Carbon Black	100	3.7	7.0	84.0	98.8	100.0	0
Lampblack	100	4.6	7.2	71.9	96.8	100.0	0
Bone Black	100	3.7	5.9	80.3	98.9	100.0	0
Cottrell Ash	200	2.8	6.0	96.7	99.6	100.0	0
Illinois Fly-Ash	200 to 325	5.4	20.1	79.6	93.5	96.0	95.3
Illinois Fly-Ash	325	4.4	9.7	80.9	94.9	98.3	57.5
Pocahontas Ash	200 to 325	8.9	22.3	60.4	84.4	91.9	89.0
Pocahontas Ash	325	3.9	10.3	84.6	96.9	98.9	43.8

Later in this test series it was discovered that the lampblack used was of slightly different density and other characteristics than that used in the first series, and that the dust arrestances for Filters *A*, *B*-1, and *C* were materially higher for this lampblack when used alone than for the same filters on the previous lampblack. Since only 20 per cent of lampblack was used in the dust mixture of the present tests, this difference on the final results would not be great, but it would have a tendency to raise the arrestance of those tests made at the 2-g rate with the new lampblack. It should be noted that the rate of 2 g per hour as fed corresponds to 0.617 grains per 1000 cu ft, which is comparable to the dust concentration in the air of industrial districts. This rate of feed is only eight times the normal dust concentration in the laboratory air, whereas a feed of 40 g per hour is 160 times normal.

The conclusion drawn from the tests shown in Table 1 is that for typical filters the arrestance values at low rates of dust feed are substantially the same as those for the 10- to 100-g rates. Since the higher rates are more practical for actual filter performance tests, it is reasonable to use them. The tests at the 2-g rate were not continued for a sufficient length of time to determine the effect of this low rate of dust feed on the life of filters, but obviously such tests are virtually impossible from the standpoint of time required.

Dust Particle Size and Filter Performance

The object of this part of the program was to determine the particle size distribution for different kinds of dusts screened to different sizes, and to find the effect of particle size on the performance of different types of filters. The analysis for particle size was made for all dusts used excepting Fuller's Earth, but the effect of particle size on filter performance was only determined for Illinois fly-ash and Pocahontas ash for two different ranges of screenings.

The results of the dust particle size analysis are shown in Table 2. When one figure is given in the column headed *Screen Mesh,* it indicates that all dust particles passed a screen of that mesh. When two figures are given it indicates that all dust particles passed the larger screen and were retained on the finer screen. In making the analysis of particle size from the screened samples a small portion of the dust was placed on a glass slide and covered by a drop of turpentine. The slide was then tapped until the dust particles had distributed themselves in the turpentine, after which the turpentine was evaporated leaving the dust particles exposed on the glass surface. Microphotographs were then made of these samples and used for measuring dust particle size. Results given in the table are the averages of from 300 to 500 particles for each sample of dust. Since the arrestance of a filter is based on the percentage, by weight, of the dust removed, it would appear that the figures in the column headed *Approximate Diameter of Particle with Average Volume* are better measures of the qualities of dust as a filter test material than are the figures giving the approximate average diameter of particles. The volume increases as the cube of the diameter increases and weights of the dust particles are in direct relation to their volumes.

Referring to the distribution of particle sizes in the various samples, it is interesting to note that for the carbon black, lampblack, bone black, and Cottrell ash, all of the particles are below 25 microns in diameter, even though the 100-mesh screen used for the first three samples would pass 147-micron diameter particles and the 200-mesh screen used for the Cottrell ash would pass 74-micron diameter particles. It should be noted, however, that carbon black and lampblack have a tendency to agglomerate and it is very difficult to pass them through a screen finer than 100-mesh, even though the individual particles should all pass a 325-mesh screen. The Cottrell dust could all have been screened through a 325-mesh screen as it does not agglomerate. In the case of the Illinois fly-ash and Pocahontas ash two different ranges of particle sizes were screened. The figures giving particle size distribution show that a large number of the fine particles were retained on the 325-mesh screen. As a matter of fact the greater number of particles of Illinois fly-ash and Pocahontas ash which were retained on the 325-mesh screen should have passed this screen. This retention was caused probably by many of the small particles adhering to larger ones and thus being prevented from passing the screen.

An interesting point to consider is the large percentage in total weight of dust samples accounted for by the very small percentage of particles over 25 microns in diameter. This is shown very clearly for the Illinois fly-ash screened between 200- and 325-mesh, and to a slightly lesser extent for the Pocahontas ash screened to the same size. This is a very important point to consider when selecting a dust to be used for testing a filter on the weight basis. A small percentage of large sized particles may have an undue influence on the filter arrestance. While a large percentage of the weight of the coarsely screened coal ash dusts are made up of particles above 25 microns in diameter, all of the particles of these samples were of the type which float readily in the air.

An attempt was made to use the dust from Illinois fly-ash and Pocahontas ash screened between 100- and 200-mesh, but many of these particles were so heavy that they settled out of the air very rapidly and were impractical for filter tests. The particle sizes which should pass the different screens are as given:

Screen Size	Dust Particle Size Microns
100	147
150	104
200	74
325	43
400	38

From the results of Table 2 it would appear that carbon black, lampblack and bone black might be screened through a 100-mesh screen, Cottrell ash either through a 200- or 325-mesh screen, and Illinois fly ash and Pocahontas ash should be screened through a 325-mesh screen. From the table of screen sizes it is evident that nothing would be gained by screening finer than 325-mesh.

An attempt was made to grade further the particles of Illinois fly-ash and Pocahontas ash which passed through the 325-mesh screen by a process of elutriation. It was found that when these dusts were mixed with a solution of water and alcohol only about 1.2 per cent would remain in suspension for a period of one hour. As this was the minimum time that would show a definite difference in diameters of particles which settled out and which remained in suspension, the method was abandoned as impractical.

Table 3 shows the performance characteristics of each of the four filters when using the fine and coarse screened Pocahontas and Illinois fly ashes. The test results for the Pocahontas ash are shown in the curves of Figs. 2, 3, 4 and 5 for Filters *A*, *B*-1, *C*, and *D* respectively. The Illinois fly-ash was not used for Filter *A*. This was due to the time required and to the probability that nothing new would be gained over the results for the other tests.

From the curves it will be noted that the dust arrestance was maintained uniformly throughout the test

Table 3—Comparison of Filter Performance on Different Dust Particle Sizes[a]
(Dust Feed 40 grams per hour. Air face velocity 300 fpm)

Type of Dust	Approx. Diam. of Particle with Average Volume	Filter *A*			Filter *B*			Filter *C*			Filter *D*		
		Arres. Per Cent	Life Hours	D. H. C.[b] Grams	Arres. Per Cent	Life Hours	D. H. C.[b] Grams	Arres. Per Cent	Life Hours	D. H. C.[b] Grams	Arres. Per Cent	Life Hours	D. H. C. Grams
Pocahontas Ash.......	10.3	91.4	16.0	585.6	93.2	6.7	249.8	77.7	10.3	325.5	94.5	13.5	511.0
Pocahontas Ash.......	22.3	94.4	16.0	604.1	93.5	7.4	277.4	84.9	12.9	441.8	91.8	12.7	464.0
Illinois Fly-Ash...	9.7	—	—	—	96.3	10.8	415.9	81.6	13.9	457.7	94.6	30.4	1152.8
Illinois Fly-Ash...	20.1	—	—	—	96.2	15.3	588.9	83.3	15.0	497.0	90.6	—	—

[a] Results based on a resistance rise of 0.15 in. of water across the filter.
[b] Dust holding capacity.

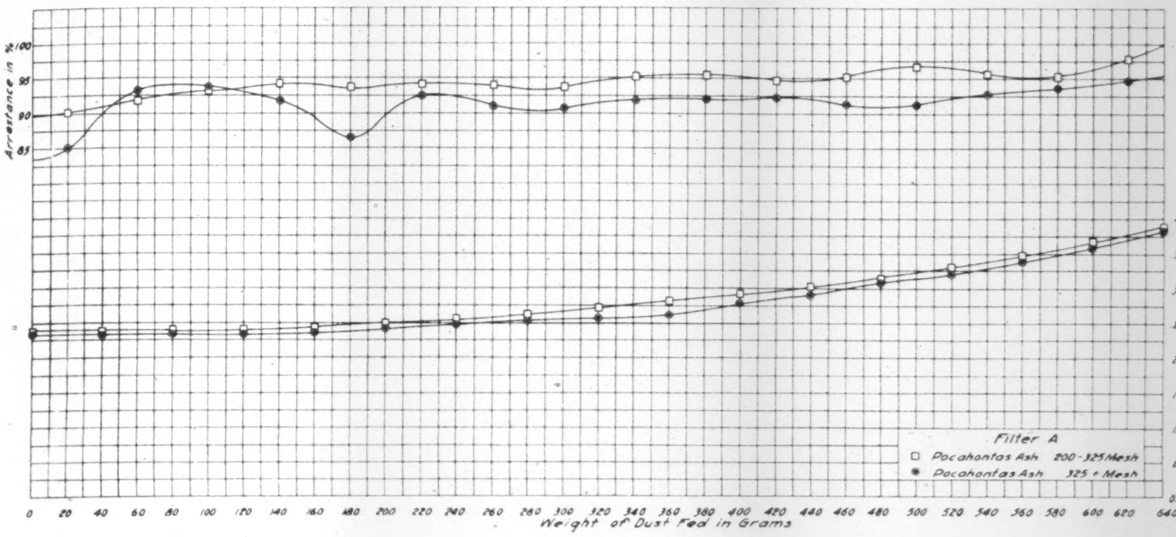

Fig. 2—Effect of Pocahontas dust particle size on performance of Filter *A*. Dust feed, 40 g per hour

period for all filters excepting Filter *C,* in which case it gradually decreased as the test progressed. This also had a tendency to increase the life of the filter. The tests presented later on for the same filter with dust mixtures showed substantially uniform results throughout the test period at the same rate of dust feed. The reduction in arrestance cannot be interpreted, therefore, to indicate that 40 g per hour is loading the filters too rapidly when mixtures containing some carbon are used.

An analysis of the test data in Table 3 and the curves indicates that the performance characteristics for Filters *A*, *B*-1, and *C* are slightly better when using the coarser ash, the greatest difference in arrestance being for Filter *C*. For Filter *D*, however, the results are reversed. When using the Illinois fly-ash in Filter *D* it was found that the coarse ash had a tendency to drop off from the face of the filter making it impossible to complete the test without giving misleading results. This was not true of the fine mesh dust as the cotton filtering pad was weighed before and after the test accounting for all but 4.95 per cent of the weight of dust taken out of the air by the filter. A part of this loss was accounted for by the dust which actually fell off from the filter media in removing it from the frame. The results of this part of the investigation, indicate that the finer dusts are better adapted to the rating of filters, and it is recommended that if either Pocahontas or Illinois fly-ash is to be used it should be screened through a 325-mesh screen.

Different Types of Carbon and Filter Performance

The filter test code states that the standard dust shall contain 50 per cent by weight of powdered lampblack containing 97.5 per cent of free carbon minimum, and having a bulking value of 3½ lb per cu ft minimum. Previous investigations have shown that there are many different types of carbon that will fill this requirement and that some of them have a marked effect on the performance of a filter. Even though the specification is limited to lampblack there is still a wide latitude in materials which could be selected to meet the code requirement. This uncertainty as to the characteristics of a suitable lampblack and the handicap which large percentages of some lampblacks place on many filters lead to the selection of a dust mixture for rating air filters for railroad applications[2] which contained only 20 per cent of lampblack instead of the 50 per cent required in the code. This change in the dust specification minimized the difficulty but did not eliminate it.

In order to find out more about the different grades of carbons and their effect on filter arrestance, four materials were selected and a study was made of the effect of these materials on the performance characteristics of the four types of filters. The materials were as follows: Lampblack, Germantown Eagle Brand, manufactured by L. Martin and Co.; Carbon Black, No. 5 grade, manufactured by Binney and Smith Co., New York City; Bone Black; No. 7 *Cosmic Black,* manufactured by American Agricultural Chemical Co., Detroit, Mich.; Soot, removed from the flues of an oil burning installation in which there was incomplete combustion. These materials were all screened through a 100-mesh screen. The analysis is shown in Table 2. The points to note are that all dusts are made up of very fine particles, the largest per cent in each case being less than 5 microns in diameter. The densities, however, as shown

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[2] Loc. Cit. See Nete 1.

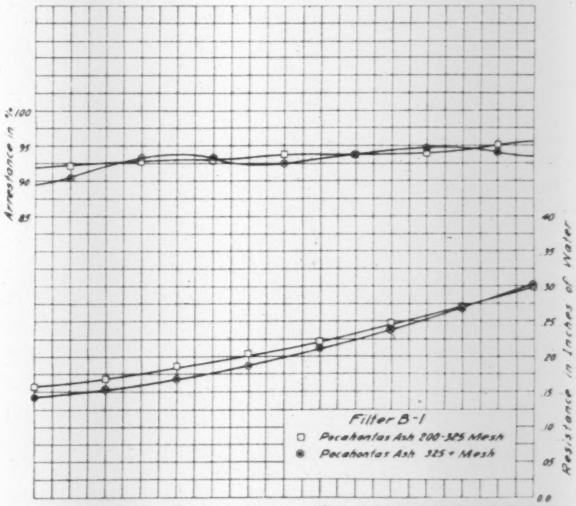

Fig. 3—Effect of Pocahontas dust particle size on performance of Filter *B*-1. Dust feed, 40 g per hour

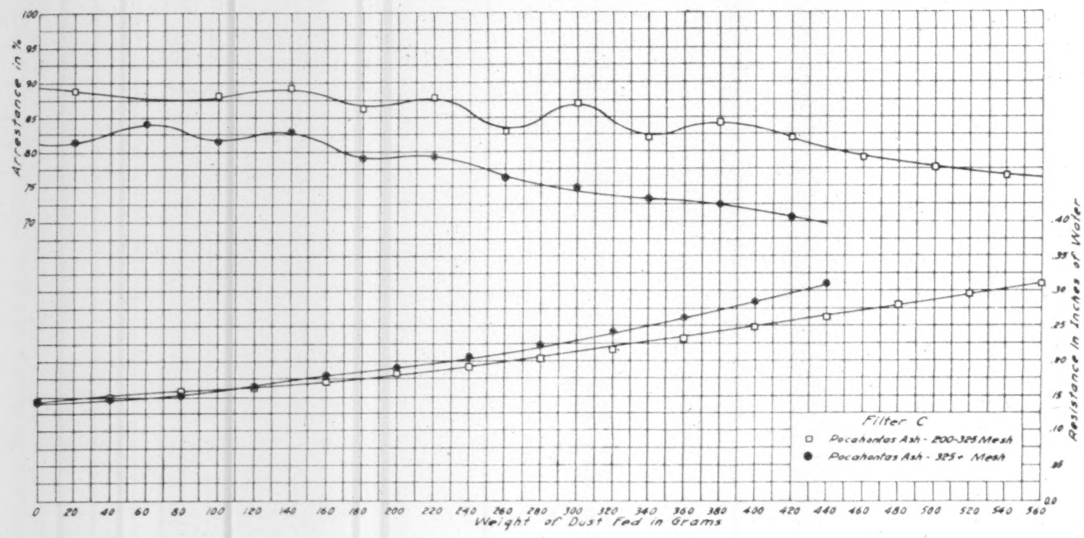

Fig. 4—Effect of Pocahontas dust particle size on performance of Filter *C*. Dust feed, 40 g per hour

in Table 4, are very different, the bone black being over three times as heavy as any of the other three. The bone black was more granular and did not agglomerate as did the other carbon dusts.

The results for the performance tests of the four filters when using each of the carbon dusts are shown in Table 4 and in Figs. 6, 7, 8 and 9 for Filters *A*, *B*-1, *C* and *D*, respectively. The results of these tests show that the arrestances for all four filters are in the order of carbon black, lowest; lampblack, second; and bone black, highest. As to the life and dust holding capacity, lampblack resulted in the poorest performance values, carbon black next, and bone black best, with the one exception of Filter *A*, in which case the dust holding capacities were about the same for carbon black and lampblack. For each case the life and dust holding capacity when using bone black were decidedly longer than for the other types of carbons. In the case of soot the tests were made for short periods on Filters *B*-1, *C*, and *D*. The arrestance of the soot was closer to that of carbon black than to that of lampblack. The density of the soot used was less than that of either the lampblack or the carbon black; therefore the life and dust holding capacity probably would be less for this material if complete tests were run. In making this investigation of different types of carbon dust the results obtained from the lampblack were very different from those obtained from the same brand of lampblack in previous tests on identical filters. The arrestances were very much higher and the life of the filter was somewhat shorter. For this reason an investigation was made to determine the variations in lampblack samples of the same brand.

Table 5 shows the results of tests on Filters *A*, *B*-1, *C* and *D* when using the lampblack of the previous series and that of the present series of tests. In all cases the dust arrestance and the rise in air resistance across the filter per hour when using the dust of the second series were much higher than when using the dust of the first series. It was thought at first that the relative humidity of the air at the time of test might have had some effect on the arrestance values. However, a comparison of these humidities, as taken at the time of test and shown in Table 5, showed no relationship between humidity and arrestance. It should be noted that when tests were re

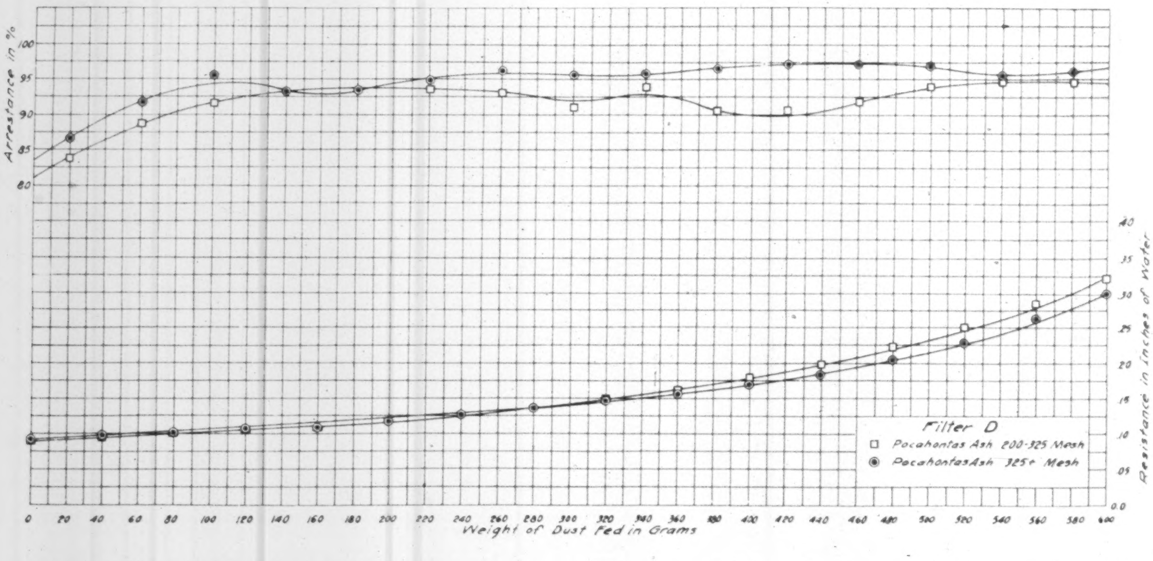

Fig. 5—Effect of Pocahontas dust particle size on performance of Filter *D*. Dust feed, 40 g per hour

Table 4—Comparison of Filter Performance[a] on Different Carbons
(Dust Feed 40 grams per hour. Face air velocity 300 fpm)

ype of Dust	Dust Density (Jolted)		Filter *A*			Filter *B*-1			Filter *C*			Filter *D*		
	Grams/ cc	Pounds/ cu ft	Arr. Per Cent	Life Hours	D.H.C. Grams	Arr. Per Cent	Life Hours	D.H.C. Grams	Arr. Per Cent	Life Hours	D.H.C. Grams	Arr. Per Cent	Life Hours	D.H.C. Grams
Lampblack....	0.203	12.7	75.9	4.8	146.6	66.0	1.8	45.2	45.4	2.8	50.8	82.0	0.9	29.5
Carbon black..	0.210	13.2	71.4	5.1	145.8	58.2	3.1	71.0	29.4	6.2	72.4	80.9	1.5	48.5
Bone black....	0.741	46.3	78.7	26.9	838.4	81.8	11.8	386.0	58.2	12.5	292.4	84.7	10.8	365.4
Soot..........	0.135	8.45	....	......	....	58.9	......	....	29.7	......	....	66.9	......	....

[a] All values based on a resistance rise of 0.15 in. of water across filter.

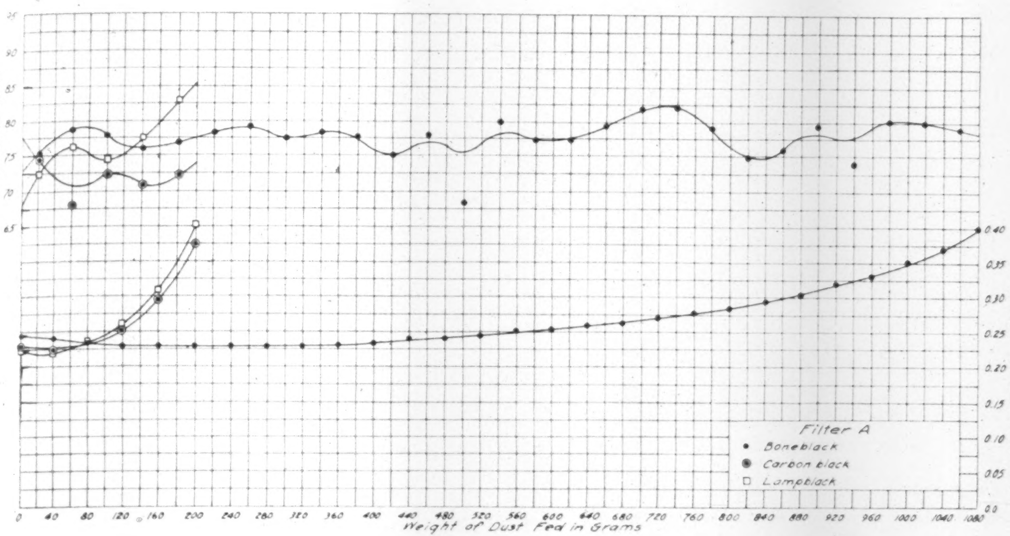

Fig. 6—Effect of different carbons on performance of Filter *A*. Dust feed, 40 g per hour

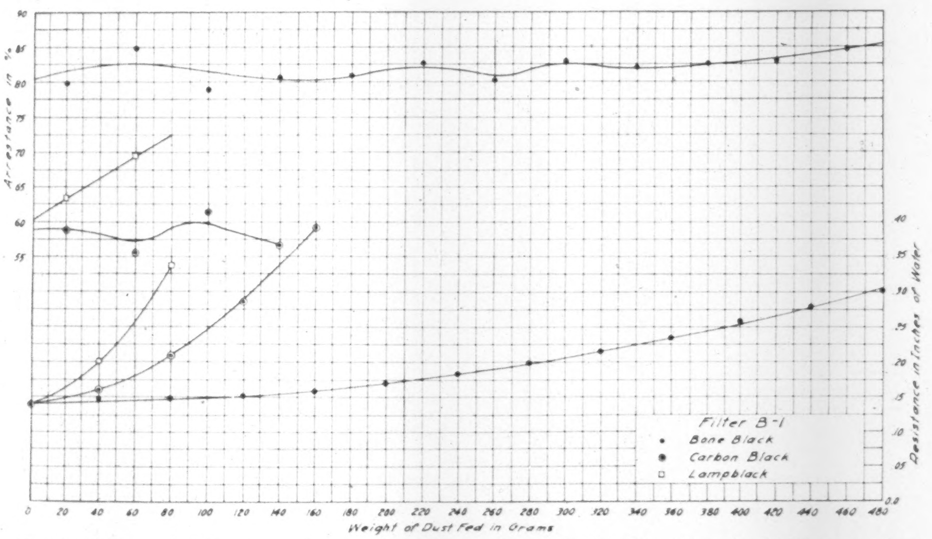

Fig. 7—Effect of different carbons on performance of Filter *B*-1. Dust feed, 40 g per hour

peated using the same filter and lampblack from the same lot the values were substantially uniform. In each series of tests enough lampblack was purchased at the beginning of the series for the entire investigation so that the test values of a series are comparable within themselves, but the results for the different series may not be strictly comparable even though the same brand of lampblack was used.

After it was discovered that a wide range in test values might result from the same lampblack purchased at different periods, samples of the same brand were selected from as many sources as possible and a series of tests was run on Filter *B*-1, the results of which are shown in Table 6. Test No. 114, the last one shown in this table, was taken from the first series. This dust had the lowest density, gave the lowest arrestance value, had the lowest resistance rise per hour, and the longest filter life. The arrestance values for the lampblack of later selection ranged from 46.7 to 82.4 per cent. There does not seem to be a strict correlation between density of lampblack and arrestance values.

From the investigation thus far made on carbon it appears that lampblack and carbon black are most nearly related to soot. Soot probably corresponds reasonably well to the carbon found in the air. Bone black does not have the required characteristics. The variations in test results for lampblack of the same brand but selected from different lots is so great that further investigation is necessary in order to select a standard carbon for test purposes. This part of the investigation is now being continued.

Dust Density and Filter Performance

The relation between filter performance and density of dust is shown by the tabulated results in Table 7 and by the curves of Fig. 10. From the table it will be noted that the density of soot, the lightest dust, is about one-tenth that of Cottrell ash, the heaviest dust; the lampblack and carbon black used were of substantially the same density, about one-sixth that of Cottrell ash. The finely screened Pocahontas ash was slightly heavier than the coarsely screened ash, but the reverse was true of the Illinois fly-ash. In all cases Illinois fly-ash was slightly heavier than the Pocahontas ash, but the Cottrell ash was 50 per cent heavier than either of the other two for the same volume.

Table 5—Arrestance[a], Resistance Rise[a], and Relative Humidity During Test, For Filters *A*, *B*-1, *C*, and *D* on Two Lots of Lampblack[b]

Dust	Filter *A*			Filter *B*-1			Filter *C*			Filter *D*		
	Arr. Per Cent	Resistance Rise In. Water/Hour	Per Cent R.H.	Arr. Per Cent	Resistance Rise In. Water/Hour	Per Cent R.H.	Arr. Per Cent	Resistance Rise In. Water/Hour	Per Cent R.H.	Arr. Per Cent	Resistance Rise In. Water/Hour	Per Cent R.H.
Performance with first lot Lampblack	21.7	0.001	46	27.8	0.008	46	23.3 17.1	0.007 0.007	46 42	74.1	0.096	
Performance with second lot Lampblack	74.3	0.013	45	65.2 56.8 63.2	0.098 .... 0.084	40 22 24	45.4 37.7 36.8	0.055 0.074 0.079	22 26 40	82.5	0.175	29

[a] Based on 3-hour average.
[b] Both lots same brand from same manufacturer.

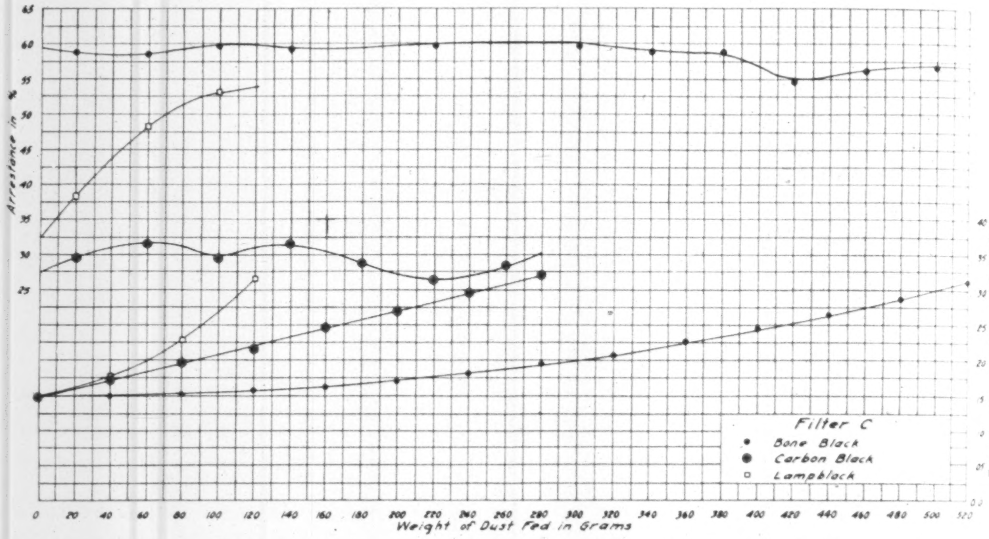

Fig. 8—Effect of different carbons on performance of Filter *C*. Dust feed, 40 g per hour

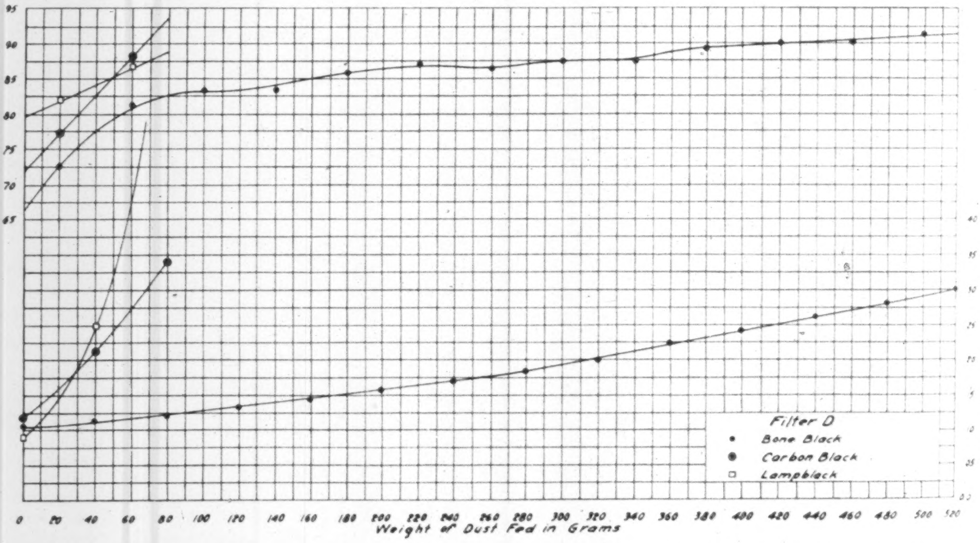

Fig. 9—Effect of different carbons on performance of Filter *D*. Dust feed, 40 g per hour

The life in hours and dust holding capacity in grams were both determined on a basis of 0.15 in. of water increase in resistance across the filter. The graphical relation between dust holding capacity and dust density is similar to that for life and dust density, but lack of space does not permit its inclusion. In all cases the life and dust holding capacities increase with increased density. This is to be expected since each filter has a definite volumetric dust holding capacity, and for the heavier dust the volumetric feed is in inverse relation to the density. The arrestance values, as shown in Table 7, do not bear the same direct relation to the density of the dust, as there is only a slight positive correlation between the two. For filters *A*, *B*-1, and *C* the arrestance values are considerably lower for soot, lampblack and carbon black, and for Filter *D* they are slightly lower for these dusts than for the others. There are apparently other factors than dust density which affect the arrestance values. This is evident by the variations in results for the different lampblacks, even though the densities were substantially the same (See Table 6).

Both the life and dust holding capacity of all filters show a decided increase as the density of the dust is increased, with a constant weight of dust feed per hour. If, however, the dust holding capacities are based on volume of dust feed, there is a much closer relation between dust holding capacity and different types of dust for the same filter. This relation is shown in Table 8. In general lampblack and carbon black show the lowest volumetric capacities for each filter. For Filters *A*, *B*-1, and *C* the coarsely screened Pocahontas and Illinois fly-ash show slightly greater capacities than for finer screened ashes, but for Filter *D* the results are in the inverse order.

In rating a filter for life and dust holding capacity it seems evident that a dust should be selected which not only has the proper grain size, but also one which has a density which corresponds reasonably well with the density of dust to be found in the air. Of the coal ashes used,

Table 6—Comparison of Lampblacks[a] on Filter *B*-1
(Dust feed 40 grams per hour. Face air velocity 300 fpm)

Test No.	Av Arres. for 2 Hours	Life[b] in Hours	Av Resis.[c] Rise per Hour	Dust Density	Dust Sample	Source
256	78.8	1.8	0.088	0.183	1	A
257	74.0	1.8	0.089	0.213	2	
258	78.4	1.9	0.084	0.203	3	
259	75.6	2.3	0.063	0.206	4	
260	71.1	2.1	0.074	0.209	6	B
252	82.4	1.9	0.087	Approx. same as 1, 2, 3, 4	—	A
211	64.4	1.9	0.084		—	
212	56.8	—	—		—	
217	66.2	1.8	0.098		—	
255	58.4	1.5	0.049	0.265	5	C
261	46.7	2.3	0.066	0.238	7	D
114	28.1	Approx. 4.5	0.024	0.156	—	

[a] All lampblacks same brand and same manufacturer but from different supply houses.
[b] Based on final resistance of 0.30 in. of water across filter.
[c] Based on 2-hour average.

it appears that Pocahontas should have the highest rating and Cottrell ash the lowest rating as to this quality.

General Comparisons of Filter Performance

The relative values for arrestance, life in hours, and dust holding capacity in grams, for the four types of filters tested with different types of dust are shown graphically in the diagrams of Figs. 11, 12 and 13. The life in hours and dust holding capacity in grams were based on an air resistance rise across the filter of 0.15 in. of water. The average initial test resistances of the filters at 300 fpm face velocity air were as follows:

A—0.233 in. water
B-1—0.145 in. water
C—0.149 in. water
D—0.101 in. water

All filters were 2 in. in thickness excepting *A* which was 4 in. in thickness. It is recognized that a resistance rise of 0.15 in. of water is less than that specified in the code or than would be expected in practical operation of the filters. This limit was used, however, because of the excessive time that would have been required to run all tests up to a final filter resistance of 0.4 or 0.5 in. of water. The low limits of resistance used should not have any effect on the comparative results for a given filter when using different types of dust, but might have some effect on the comparative values for different filters on the same dusts.

The arrestance values from Fig. 11 show a wider spread for the values of different filters when using lampblack and carbon black than when using the other types of dust. All filters show satisfactory arrestance values when using any of the ash materials. Filter life, as shown in the diagram of Fig. 12, is very short in all cases when using lampblack and carbon black. In general, it is the longest when using Cottrell ash. The dust holding capacities in grams as shown in Fig. 13 follow substantially the same relation as the values giving life in hours. In general, as previously pointed out, the lighter weight dusts show low dust holding capacity and life due to the volumetric limitations of the filters. It should be noted that no one type of filter is best for all types of dust.

Table 9 shows the life comparison of three filters, *B*-1, *C*, and *D*, when tested with a given mixture of dust and compared with the weighted life for the same filters tested with the individual dusts of the mixture. The figures in the last column show that there is a low correlation between the weighted and actual test values, the weighted life being the greatest in all cases. In other words, when two dusts are used in a mixture, one of which gives a short life to the filter and the other a long life, the short life dust has a greater effect on the life of the filter than would be expected from its actual percentage in the mixture. This is in contrast to the results obtained by weighting the values for filter arrestances of individual dusts and comparing them to the arrestance values for the combined dust. In this case there was a very high correlation of results, as reported in the previous paper.

Figs. 14, 15, 16, and 17 show the

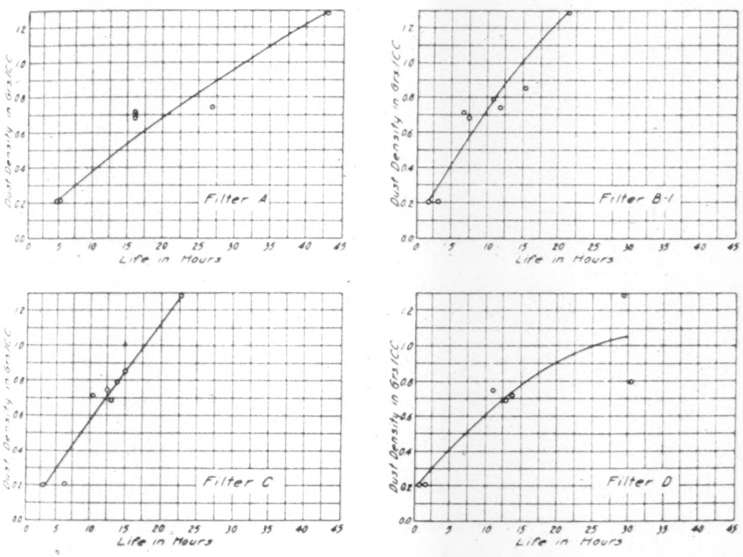

Fig. 10—Effect of dust density on filter life. Dust feed, 40 g per hour

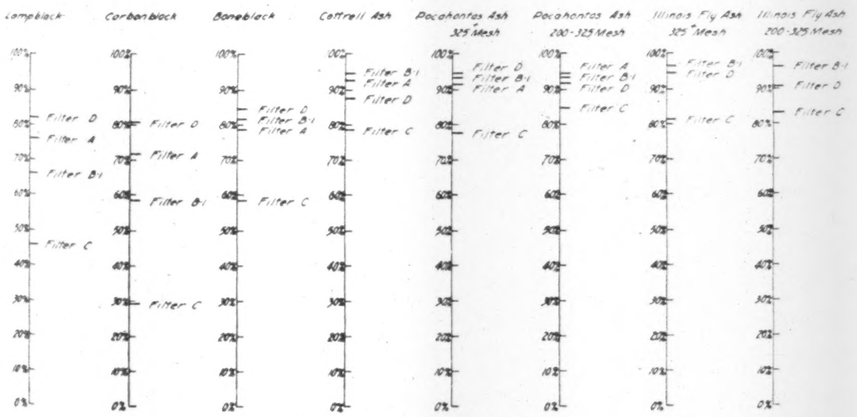

Fig. 11—Comparative filter arrestances for different dusts. Dust feed, 40 g per hour

Table 7—Relation Between Dust Density and Filter Performance[a]
(Dust Feed 40 grams per hour. Face air velocity 300 fpm)

Type of Dust	Dust Density		Dia. Particle, Microns, with Av Vol.	Life in Hours				Dust Holding Capacity in Grams				Arrestance in Per C		
	Grams/cc	Pounds/cu ft		*A*	*B*-1	*C*	*D*	*A*	*B*-1	*C*	*D*	*A*	*B*-1	*C*
Soot	0.135	8.45	—	—	—	—	—	—	—	—	—	—	58.9	29.7
Lampblack	0.203	12.7	7.2	4.8	1.8	2.8	0.9	146.6	45.2	50.8	29.5	75.9	66.0	45.4
Carbon black	0.210	13.2	7.0	5.1	3.1	6.2	1.5	145.8	71.0	72.4	48.5	71.4	58.2	29.4
Pocahontas 200-325	0.686	42.8	22.3	16.0	7.4	12.9	12.7	604.1	277.4	441.8	464.0	94.4	93.5	81.9
Pocahontas 325+	0.718	44.8	10.3	16.0	6.7	10.3	13.5	585.6	249.8	325.5	511.0	91.4	93.2	77.7
Boneblack	0.741	46.3	5.9	26.9	11.8	12.5	10.8	838.4	386.0	292.4	365.4	78.7	81.8	58.2
Illinois Fly-Ash 325+	0.795	49.7	9.7	—	10.8	13.9	30.4	—	415.9	457.7	1152.8	—	96.3	81.6
Illinois Fly-Ash 200-325	0.857	53.5	20.1	—	15.3	15.0	—	—	588.9	497.0	—	—	96.2	83.3
Cottrell Ash	1.285	80.4	6.0	43.0[b]	21.4	22.6	29.2	1590.0[b]	815.1	709.4	1021.6	92.3	94.7	78.4

[a] All values based on a resistance rise of 0.15 in. of water across filter.
[b] Estimated value.

performance curves of Filters *A*, *B*-1, *C* and *D* respectively when using two different dust mixtures, the first consisting of 50 per cent Pocahontas ash and 50 per cent lampblack as described by the Code, and the second containing 50 per cent Pocahontas ash, 20 per cent lampblack, 20 per cent Illinois fly-ash, and 10 per cent Fuller's Earth. All filters show a marked reduction in arrestance and life when using the Standard Code dust as compared with the 50-20-20-10 mixture. Fig. 18 shows the performance curves for the same filters when using Cottrell ash. This ash has been used unmixed, in some cases, as a test dust. From a comparison of the curves for the different dust mixtures and Cottrell ash it will be noted that in all cases the filter life was longest when using the Cottrell ash. For Filters *A*, *B*-1, and *C* the arrestances were higher when using the Cottrell ash than for either of the two dust mixtures. For Filter *D* the arrestance was lower when using the Cottrell ash.

While it is apparent that a dust mixture containing 50 per cent of lampblack as called for in the Standard Code probably penalizes the performance of most filters, it is also evident that Cottrell ash is not an ideal dust to use for rating air filters because its high density results in performance characteristics better than those to be expected in practice. The 50-20-20-10 mixture seems to be preferable to the other two test dusts used, but there still is a question as to whether this mixture has all of the qualities for a practical dust mixture to be accepted as a standard for test purposes. It seems probable that a satisfactory standard dust might be made up of not more than two or three components. These components should be of low density. Further investigation should be made in order to select a carbon dust, as well as ash dust, which can

Table 8—Dust Holding Capacities[a] in Cubic Centimeters

Type Dust	Density (Jolted) Grams/cc	Rate of Feed[b] in cc/Hour	Dust Holding Cap. in			
			Filter *A*	Filter *B*-1	Filter *C*	Filter *D*
Lampblack	0.203	199	722	222	251	146
Carbon black	0.210	190	693	338	345	231
Pocahontas Ash 200-325 mesh	0.686	58	881	404	644	677
Pocahontas Ash 325 + mesh	0.718	56	816	348	453	711
Boneblack	0.741	54	1130	522	395	492
Illinois Fly-Ash 325 + mesh	0.795	50	—	522	575	1150
Illinois Fly-Ash 200-325 mesh	0.857	47	—	688	580	—
Cottrell Ash	1.285	31	—	635	552	795

[a] Based on a resistance rise of 0.15 in. water across filter.
[b] Based on a weight of 40 g per hour.

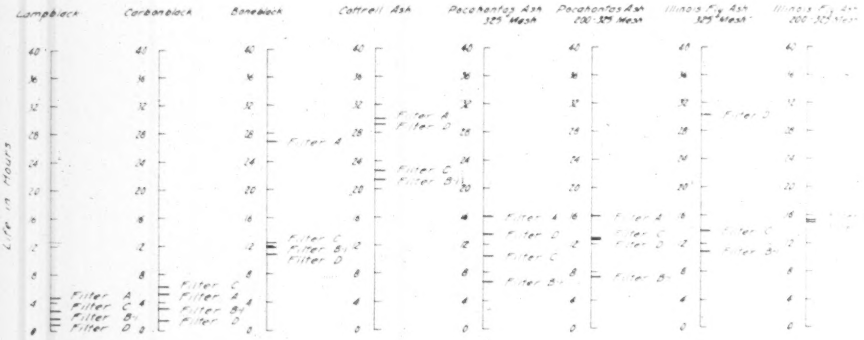

Fig. 12—Comparative filter life for different dusts. Dust feed, 40 g per hour

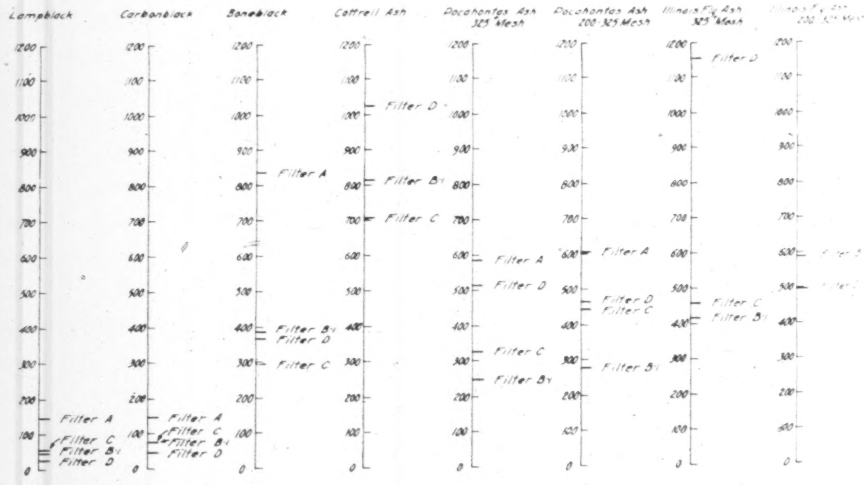

Fig. 13—Comparative filter dust holding capacities for different dusts. Dust feed, 40 g per hour

Table 9—Comparison of Actual Life of Filter with Weighted Life for 50-50 Mixture

Filter	Actual Life[a] in Hours	Weighted Life in Hours	Per Cent Actual Life of Weighted Life
B-1	3.4	4.6	73.9
C	3.9	6.8	57.3
D	2.2	8.1	27.2

[a] Based on final resistance of 0.30 in. of water across the filter.

be duplicated with reasonable accuracy.

Conclusions and Recommendations

A summary of the conclusions drawn from various sections of this discussion are as follows:

(1) In rating a filter it is not practical to duplicate the extremely low dust concentrations met in practice. Tests have shown that rates of dust feed in excess of that specified by the Standard Test Code give filter arrestances which are comparable to those obtained at the low rates found in practice. It seems desirable in revising the Air Filter Test Code to increase the rate of dust feed.

(2) In general, within the range obtainable by screening, dusts of large particle size are easier to filter from the air than similar dusts of small particle size. From the results thus far obtained it would seem preferable to screen all ash dusts through a 325-mesh screen. Further research should be made in an attempt to determine the effect on filter performance of dusts finer than those obtainable by screening.

(3) Lampblack and carbon black, both have the effect of reducing filter life and dust holding capacity when used as a test dust. Both of these carbons approximate soot fairly closely, as far as their effect on filter arrestance is concerned. It is evident that there is a wide variation in the properties of these materials, even though the dust appears to be of uniform specifications. The carbon used in a standard test dust should be of low density and should be capable of duplication as to its properties affecting filter performance. Further investigation should be made in an effort to standardize on a carbon for the standard dust.

(4) In general, filter life and dust holding capacity increase with increased dust density because of the constant volumetric capacity of a filter. There is a slight positive correlation between filter arrestance and increasing dust density. For these reasons dust density is an important factor in rating the performance of a filter on the weight basis.

(5) The present Standard Code dust of 50 per cent lampblack and 50 per cent Pocahontas ash probably penalizes the performance of most filters. On the other hand, the test dust consisting of straight Cottrell ash results in performance characteristics better than those obtainable in practice. It seems probable that a satisfactory standard dust may be made up of not more than two or three low density components.

These tests were made for the purpose of determining possible improvements in the Standard ASHVE Test Code,

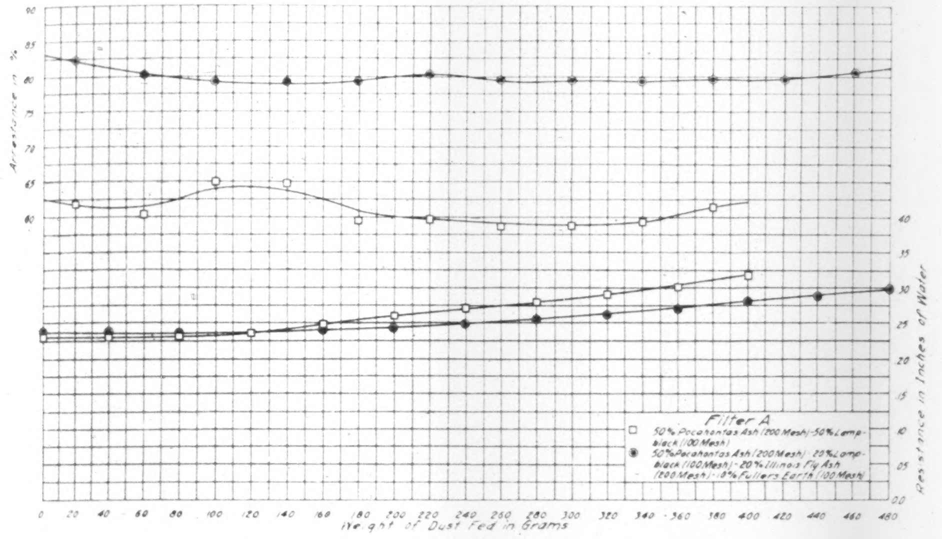

Fig. 14—Performance curves for Filter *A* on two dust mixtures. Dust feed, 40 g per hour

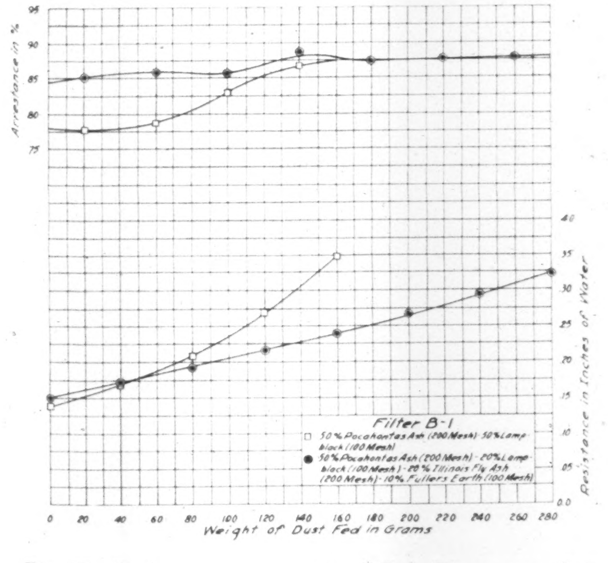

Fig. 15—Performance curves for Filter *B*-1 on two dust mixtures. Dust feed, 40 g per hour

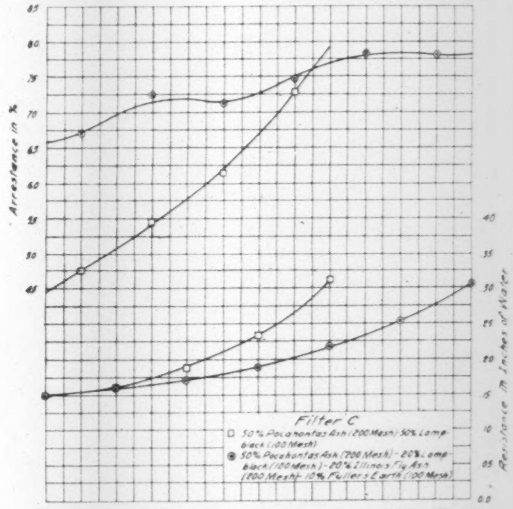

Fig. 16—Performance curves for Filter *C* on two dust mixtures. Dust feed, 40 g per hour

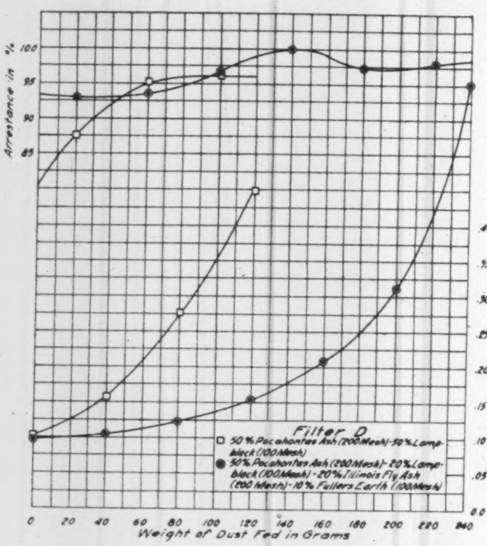

Fig. 17—Performance curves for Filter *D* on two dust mixtures. Dust feed, 40 g per hour

and not for the purpose of comparing the different filters used. To compare the merits of the different types of filters would require a much more extended series of tests and any attempt to make comparisons from the data presented here would be misleading. The filters used were selected because they were typical of their classifications, and it should not be construed that they are superior to other filters within their classifications.

Acknowledgment

The authors wish to acknowledge the cooperation of F. C. Houghten, Director, ASHVE Research Laboratory, and the Technical Advisory Committee on Air Cleaning and Atmospheric Impurities, of which H. C. Murphy is Chairman. It is also gratifying to note that the manufacturers of the various types of filters used were generous in the supply of any materials requested, and gave their full cooperation to make the program possible.

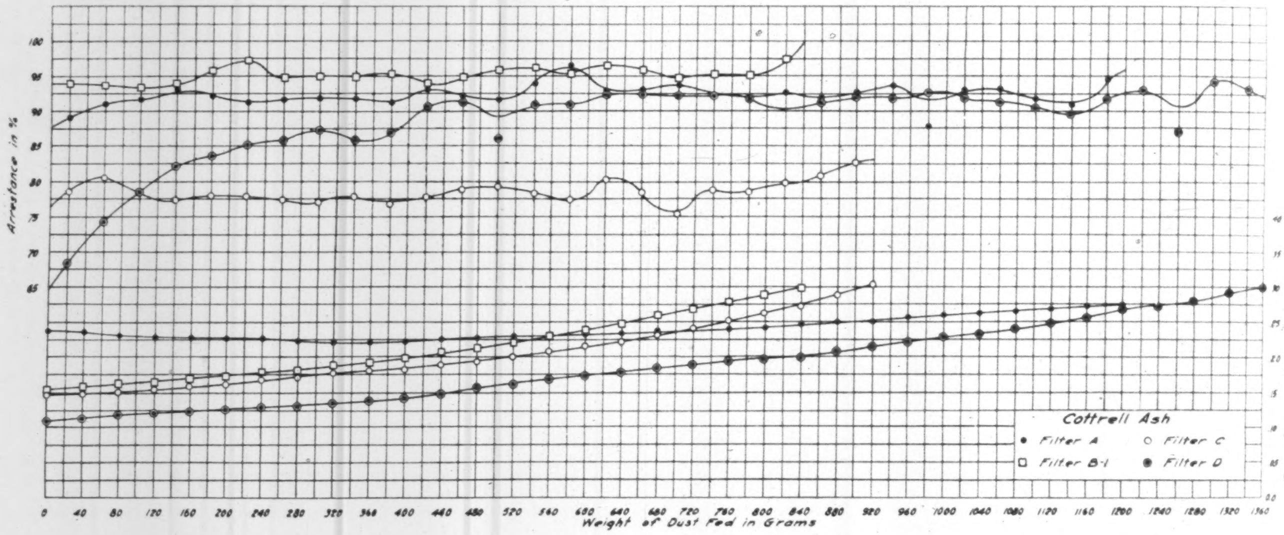

Fig. 18—Performance curves for Filters *A*, *B*-1, *C* and *D* on Cottrell ash. Dust feed, 40 g per hour

Northern Ohio Chapter Meets at Cleveland Club

April 10, 1939. At a meeting of Northern Ohio Chapter held at the Cleveland Club, dinner was served to 29, while the attendance at the business session was 42. Treas. E. W. Gray presided and the minutes of the previous meeting were read by Secy. C. M. H. Kaercher and approved. The treasurer presented a written report showing the current financial status of the Chapter and a bank balance as of April 10 of $150.98.

Reports of standing committees were in order. C. F. Eveleth of the Publication Committee gave a thorough review of current articles of interest to members. L. S. Ries reported for the Membership Committee.

The meeting then proceeded with the selection of the Nominating Committee. Nominations were offered and a written ballot resulted in the election of C. F. Eveleth, G. L. Tuve and L. T. Avery as the three members of the Committee.

The Program Committee took charge of the meeting and introduced as the guest speaker, Randolph Eide, president, Ohio Bell Telephone Co. Mr. Eide gave an interesting word picture of the telephone business and then showed sound pictures of the damage to telephone systems caused by the hurricane in New England last fall.

At the conclusion of the talk, the members expressed their appreciation to Mr. Eide by a rising vote of thanks.

Engineering Aspects of Atmosphere and Efficiency Subject of Toronto Meeting

April 3, 1939. The regular meeting of Ontario Chapter was held at the Royal York Hotel at 6:30 p.m. with 85 members and guests present.

Following dinner it was moved by J. W. Bishop and seconded by M. W. Shears that the minutes be accepted as written.

Mr. Shears reported that the Code on Hot Water and Steam Heating Systems for Homes Up to 50,000 Cu Ft Capacity is being distributed to various civic authorities and engineering organizations for their comments.

Pres. H. B. Jenney called upon E. R. Gauley to introduce the principal speaker of the evening, J. R. Hertzler, York Ice Machinery Corp., York, Pa., who spoke on Atmosphere and Efficiency in Its Engineering Aspects. A discussion followed Mr. Hertzler's address. Mr. Shears extended a vote of thanks to the speaker on behalf of the Chapter for his very instructive talk, according to the report of Secy. H. R. Roth.

Small Stokers

By Paul A. Mulcey,[*] Primos, Pa., and Ralph A. Sherman,[**]

Columbus, Ohio (*MEMBERS*)

Part 2. Small Stokers for Bituminous Coal

COAL has long been the fuel predominantly used for heating in the United States. Bituminous coal and anthracite heat over 85 per cent of the one- and two-family residences of the country. Between 15 and 20 per cent of the total production of bituminous coal, or 60 to 80 million tons of a normal production of 400 million tons, is used for domestic heating.

Most of the bituminous coal used for heating has been of the larger, so-called domestic sizes, fired by hand in central heating plants and stoves. Fired in this way, coal has the advantages of simplicity and dependability of equipment. Given the coal, which is produced in 28 states and widely distributed to the remainder, and the simplest type of fireplace, stove, furnace, or boiler and with no dependence on the availability of electric power or other utility, a home or building can be heated with little possibility of failure.

The simplicity and dependability of bituminous coal as a fuel for comfort heating have been attended by certain disadvantages. Among these are (1) dirt and smoke, (2) the tendency toward non-uniformity of heating, and (3) inefficiency in the utilization of the potential heat available in the coal. All of these difficulties may be greatly reduced, if not entirely eliminated, by intelligent methods of firing but this generally introduces a fourth difficulty, that of increased frequency of attention. Despite these disadvantages of bituminous coal and despite the availability of automatic firing devices for oil and gas earlier than for coal, coal held its position because it is, in most parts of the country, an economical source of heat.

A need for an automatic device to fire bituminous coal in heating equipment without the disadvantages of hand-firing has existed for many years. That this need was not met by manufacturers of stokers that were used under large heating and power boilers is explained by the fact that an entirely new type of engineering and merchandising was required. Whereas the firing equipment for larger boilers is more or less individually designed and adapted to each installation, the possible sales price of the smaller equipment could not absorb such individual engineering expense. New methods of mass production and mass merchandising of equipment that could be sold and installed with a minimum of time to each job were demanded.

This demand has been met and an entirely new group of manufacturers of small stokers has arisen. Although there is some overlapping in the fields of the largest sizes of one group with the smallest sizes of the other, the fields are quite distinct. The early installations of the small stokers were in the larger types of heating boilers in commercial buildings and larger homes, but the range of sizes extended downward until today the largest number of sales of stokers are those having a maximum coal burning rate of approximately 20 lb per hour. Difficulties with the early installations of the smaller sizes have been reduced by refinements produced by research and engineering developments and the satisfaction that the stokers give is proved by their increasing sales over the past few years.

From 9571 in 1932, the number of stokers sold increased to 101,808 in 1937. Of the total in 1937, 87,451 or 86 per cent were of the residential size, burning 60 lb of coal or less per hour; stokers burning bituminous coal numbered 78,377 and those burning anthracite 9074 in this class. This demand for stokers has been a part of the increasing public demand for automatic heat as the sale of oil burners and gas burners increased markedly in the same period. The sale of stokers in July, 1938, was 9061 units as compared with 10,689 oil burners.

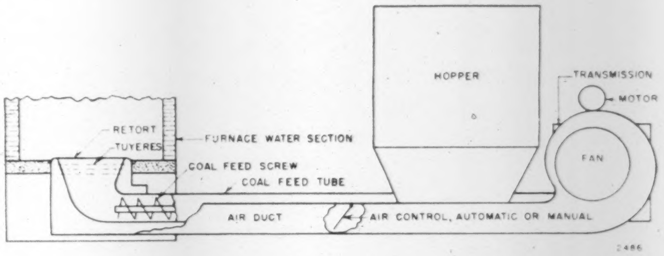

Fig. 7—Schematic diagram of conventional domestic underfeed stoker

Stokers Operate on Underfeed Principle

Although a considerable number of the small stokers designed and used for burning of the non-agglomerating coals of the far West are of the overfeed type as described by Yancey,[5] and some overfeed stokers have been made and sold in the remainder of the country, most of the stokers of the residential class and larger are of the underfeed principle. Fig. 7 shows diagrammatically the principal parts and general method of assembly of the conventional small stoker. The fractional horsepower motor has its speed reduced to 1 to 2 rpm at which the feed screw revolves by a transmission that may be of the gear or hydraulic type. The screw moves the coal from the hopper, which has a capacity of 250 to 400 lb of coal, through a cylindrical feed tube into the bottom of the retort shown at the left of the figure.

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[*] Assistant Director, Anthracite Industries Laboratory, Primos, Del. Co., Pa., Author, Part I.

[**] Supervisor, Fuels Research Laboratories, Bituminous Coal Research, Inc., and of Fuels Division, Battelle Memorial Institute, Columbus, Ohio, Author, Part II.

Part I, Domestic Anthracite Burners, published in May, 1939.

Presented at the 45th Annual Meeting of the AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS, Pittsburgh, Pa., January, 1939.

[5] Burning of Various Coals Continuously and Intermittently on a Domestic Overfeed Stoker, by H. F. Yancey. (Report of Investigation 3379, *Bureau of Mines*, January, 1938).

The retort may be either round or rectangular. Round retorts are more common in the smaller sizes of stokers and rectangular retorts are the rule for large stokers. The coal moves upward in the retort past the ports or tuyeres distributed in one to four rows around the inside of the retort near the top. A row of tuyeres is also commonly provided around the outside of the retort at the top.

Air for combustion is provided by a centrifugal fan, the rotor of which may be mounted directly on the shaft of the motor or driven through a V-belt. A damper, which may be manual or automatic, is provided in the air duct or on the inlet of the fan for adjustment of the rate of supply of air.

Because pieces of foreign material that will catch between the flight of the feed screw and the entrance to the feed tube may be placed in the hopper with the coal, a removable plate is generally provided at the junction of the hopper and the feed tube for removal of the obstructing piece. A shear pin, an electrical-overload switch, or a hydraulically-operated switch in hydraulic transmissions or combinations of these is provided for protection of the motor from overloads caused by jamming of the feed screw. To minimize or prevent arching of wet coal in the hopper, many stokers are provided with agitating devices in the hopper.

For further discussion of the details of the design of small stokers and the principles underlying the trends in design, the reader is referred to a recent paper by Guthrie.[6]

Installation of Stokers

Stokers are normally installed with the top of the retort at the level at which the grate was or would be. A steel plate may be used between the retort and the walls of the combustion chamber or more generally the space below the level of the hearth is filled with bricks and sand. Above the steel plate or filling, the hearth is formed with plastic refractory. In larger installations, cast-iron dead plates are used instead of refractory and in some of the largest installations dumping side grates are used.

Because one of the principal advantages of a stoker installation over hand firing is the possibility of combustion without smoke, the installation should be made with ample distance between the hearth and the heating surfaces and with ample combustion volume to obtain proper mixing and prevent smoke. Standards for setting heights and combustion space requirements that are acceptable to stoker manufacturers, boiler manufacturers and smoke regulating departments have not yet been provided. The *Steel Heating Boiler Institute* sets a maximum limit of 60,000 Btu per cubic foot of combustion space per hour and stoker manufacturers state that this is acceptable. They report installations where this rate of heat liberation has been exceeded with satisfactory operation. On the other hand, limits as low as 35,000 and 40,000 are set by some smoke regulating departments. Arrangements are now under way for an experimental investigation to determine the proper limits for various types of coal.

Sizing of Stokers

With stokers, as with all types of firing equipment care must be exercised to have the equipment properly sized to fulfill the heating requirements. *The Stoker Manufacturers Association* has recently adopted a Uniform Stoker Rating method. The standard formula is:

$$\begin{array}{c}\text{Stoker size in pounds of coal} \\ \text{(burning rate per hour)}\end{array} = \frac{\text{Load in Btu/hour}}{\begin{array}{c}\text{Heating value of coal as burned} \\ \times \text{ overall efficiency of stoker} \\ \text{and boiler or furnace}\end{array}}$$

For warm-air furnaces the load is stated as the Btu heat loss of the space to be heated and for steam and hot water systems the load is calculated as the product of the installed radiation or its equivalent by the usually accepted heat emission factors of 240 and 150 Btu per square foot per hour, respectively, and a piping and pick-up factor of 1.33. The pick-up factor is subject to change to higher values for unusual conditions.

The value for overall efficiency of the installation suggested is 65 per cent for burning rates up to 100 lb of coal per hour and 70 per cent for rates above this. These values are only suggested average values and should be decreased or increased dependent on the particular conditions of the installation.

Process of Combustion

Through research conducted by Bituminous Coal Research, Inc., at Battelle Memorial Institute, the process of combustion of bituminous coal on the small underfeed stoker has been subjected to a detailed experimental analysis. In a series of reports by Sherman and Kaiser,[7] by Sherman,[8] and by Barnes,[9, 10] the results and conclusions have been reported in detail.

Briefly stated, these conclusions are: Combustion does not proceed by the strictly underfeed principle but by a combination of underfeed, crossfeed and overfeed principles. With most bituminous coals, the caking and coking are so favored by the rapid rates of heating in the fuel bed that masses of coke much larger than the individual pieces of coal fed to the stoker are formed. The air from the tuyeres cannot penetrate to the center of the mass of coke and combustion occurs in a ring around the periphery of the retort rather than over the entire area of the retort. The coke rises in the center, breaks up and falls into the combustion zone. The ash as released is pushed onto the hearth around the retort where it is subjected to the high temperature from the combustion zone and is fused into a ring of clinker for removal with tongs.

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[6] Small Underfeed Single-Retort Stokers, by B. M. Guthrie. (*Transactions ASME*, Vol. 60, 1938, p. 5-10).

[7] Combustion of Bituminous Coal in Small Underfeed Stokers, by R. A. Sherman and E. R. Kaiser. (*Transactions Coal Division, AIME*, Vol. 130, 1938, p. 388-407; Information Bulletin No. 2, *Bituminous Coal Research Inc.*, 1937).

[8] Automatic Residential Heating with Bituminous Coal, by R. A. Sherman. (*Proceedings*, 22nd Fuel Engineering Conference, Appalachian Coals, Inc., 1938).

[9] Fundamentals of Combustion in Small Underfeed Stokers, by C. A. Barnes. (Tech. Report No. 4, *Bituminous Coal Research, Inc.*, 1938).

[10] Some Aspects of Combustion in Small Underfeed Stokers, by C. A. Barnes. (Presented at joint meeting of Fuels Division, *ASME* and Coal Division, *AIME*, October 1938).

Selection of Coal for Underfeed Stokers

Performance tests of various typical coals have been included in the program of research of Bituminous Coal Research, Inc., and have been reported by Sherman, Kaiser, and Limbacher,[11] Limbacher and Sherman,[12] and Sherman.[13] The results of these tests have shown that of the various characteristics of bituminous coals, such as volatile content, ash content, ash clinkering tendencies, caking and coking characteristics, and size, the coking characteristics and the clinkering tendencies were the most important in determining the satisfactory performance of a coal.

The coking characteristics are of utmost importance because, although practically all coals form more or less coherent masses of coke that make a ragged-appearing, non-uniform fuel bed, if the coking is too strong certain difficulties may result. The principal difficulty is a low rate of burning and slow response to demands for heat with, in extreme cases, loss of ignition and extinction of the fire. The maintenance of a low excess of air has been found favorable toward the decrease of difficulties with coke formations, not because this reduces them but because it favors the maintenance of a strong burning zone and maintains ignition.

The usual method of removal of ash from small stoker-fired installations is as a clinker. The ash must fuse, therefore, at the temperatures reached in the fuel bed of the stoker but must not become so fluid as to run down into the retort. Barnes[14, 15] has shown that temperatures of 2400 to 2800 F are reached in the fuel bed of typical small stokers in continuous operation. With intermittent operation, as in heating installations, the maximum temperature reached over prolonged periods may be several hundred degrees lower than the maximum Barnes found.

Experience has shown that coals whose ash-softening temperatures are in the range of 2200 to 2500 F are well suited to use on the clinkering type of stoker. Cleghorn and Helfinstine[16] and Cleghorn[17] have shown that Iowa coals whose ash contents are 15 per cent and higher and whose ash softening temperatures are 2000 F and lower can be used on the small stoker and many successful installations using this type of coal confirm this finding. Coals with ash-softening temperatures as high as 2700 F have also been successfully used but difficulty is to be expected with such coals from failure to make clinker in periods of prolonged mild weather.

The size of the coal furnished for small stokers can be controlled by the producer and the importance of this characteristic has been the subject of investigation by Bituminous Coal Research, Inc., by coal producers, and by stoker manufacturers. The conclusion reached as to the top size of coal is that for the residential stoker, burning less than 60 lb of coal per hour, it should not be greater than $1\frac{1}{4}$ in.; many producers have established the top size at a lower value, as 1 in., $\frac{3}{4}$ in., and as low as $\frac{5}{16}$ in.

The lower size limit has been found by Bituminous Coal Research, Inc., to be of particular importance in the combustion process only with the strongly coking coals. With these coals it is often an advantage to remove the coal smaller than 10 mesh, $\frac{1}{4}$ in. or $\frac{3}{8}$ in. as the coking tendencies will be reduced either because of the removal of a strongly coking fraction of the coal or because of increased porosity of the bed. The effect of the removal of the finer sizes would undoubtedly be greater if it were not for the crushing action that occurs in the feeding of the coal from the hopper to the retort.

Close sizing of coal has other advantages apart from whether or not it improves the combustion performance. It reduces the segregation of the sizes that occurs in the handling of the coal, it improves the appearance of the coal, and it makes the coal more amenable to dustproofing with oil or other materials.

Close sizing has the disadvantage that it necessitates the production of a small size of coal that is difficult to handle and dispose of profitably. This results in the necessity of a higher price for the sized stoker coal than would be possible for the coal without the smaller sizes removed. The recent trend by producers has been toward the production of the closely-sized stoker coal although some adhere to the production of stoker coal without the fines removed where experiment has shown that no advantage in performance results from their removal.

The desire for cleanliness is one of the impelling motives for the purchase of a stoker for heating purposes. The coal that is used must, therefore, be free from dust. Producers recognize this and practically all of the coal marketed for small stokers is treated to eliminate dust in handling. A program of research has been sponsored at Battelle Memorial Institute on the dustless treatment of coal with oil which is one of the materials widely used for this purpose. Papers by Sherman and Pilcher [18] and by Pilcher [19] present some of the results of this investigation. They show that the type and amount of oil required for permanently effective treatment varies with the rank and the size of the coal but that all coals can be effectively treated with some of the economically available petroleum products.

Special Features of Stokers

In addition to the essential features of small stokers that were described briefly at the beginning of this paper, a number of special features are used by one or several manufacturers. The description and comment on these features have been placed after the discussion of the process of combustion and of the relation of the characteristics of coals to their performance that the purpose and action of these features might be more clearly understood.

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[11] The Relation of the Size of Bituminous Coals to Their Performance on Small Underfeed Stokers, by R. A. Sherman, E. R. Kaiser and H. R. Limbacher. (Tech. Report No. 1, Part II, *Bituminous Coal Research, Inc.*, 1937).

[12] The Performance of Several Types of Bituminous Coals on Small Underfeed Stokers, by H. R. Limbacher and R. A. Sherman. (*Bituminous Coal Research, Inc.*, 1938).

[13] Preparation of Stoker Coal, by R. A. Sherman. (*Coal Heat*, Vol. 34, August 1938, p. 5-8).

[14] Loc. Cit. See Note 9.

[15] Loc. Cit. See Note 10.

[16] Use of Iowa Coal in Domestic Stokers, by M. P. Cleghorn and R. J. Helfinstine. (Bulletin 134, *Iowa Engineering Experiment Station*, 1937).

[17] Iowa Coal as a Domestic Stoker Fuel, by M. P. Cleghorn. (Presented at Joint Meeting of Fuels Division, *ASME* and Coal Division, *AIME*, October 1938).

[18] An Experimental Investigation of the Use of Oil for the Treatment of Coal, by R. A. Sherman and J. M. Pilcher. (*Transactions, ASME*, Vol. 60, 1938, p. 97-111).

[19] Oil Treatment of Coal, by J. M. Pilcher. (Paper presented at Conference on Coal Utilization, University of Michigan, 1938).

Automatic Air Controls

The centrifugal fan that is used on most small stokers has the well-known characteristic that for any fixed setting of a controlling damper the volume or weight of air delivered varies widely as the resistance against which the fan works varies. The variations in resistance of the fuel bed that occur in the intermittent operation of a stoker used for heating will, therefore, result in wide changes in the rate of air flow although the rate of feeding coal may remain constant. Many manufacturers have equipped their stokers with dampers that function automatically to vary the natural characteristics of the fan. These dampers may function by static pressure or by velocity pressure of the air in the duct to maintain a constant flow of air regardless of the resistance of the fuel bed or to increase the flow of air as the resistance of the bed increases and to decrease the flow as the resistance decreases.

Fig. 8 shows the type of control obtained with one air control as reported by Limbacher[20] as a result of research for Bituminous Coal Research, Inc. This was of the type that was designed to maintain a constant flow of air and the flatness of the curves shows that it functioned as designed up to the cut-off pressure of the fan. Limbacher's report showed that four of the five controls tested filled their purpose adequately.

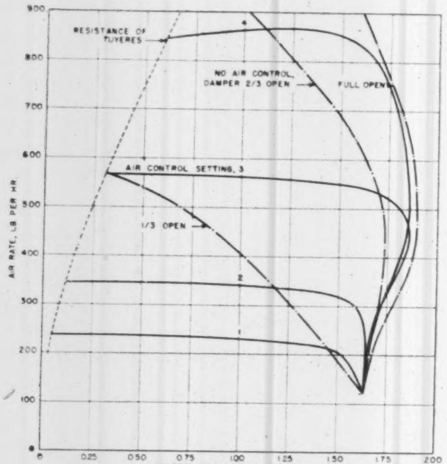

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Fig. 8—Characteristics of an air control intended to maintain a uniform air delivery as the wind-box pressure varies

Fuel Bed Depth Controls

Another method of attaining a similar end has been adopted by several manufacturers. A manually set damper is used for the control of the air but the flow is held substantially constant by control of the rate of feeding coal to maintain a constant resistance in the fuel bed. One stoker does this by the use of separate motors for the fan and the coal feed; the coal feed motor is automatically stopped when the resistance of the bed rises to a predetermined and adjustable value and is started again when the resistance decreases to another value. A variation of this method is to use but one motor with a solenoid-operated clutch between the motor and the transmission to stop the coal feed. A discussion of the operation of this type of device is given in a recent report.[21]

Fuel-Bed Agitators

As was discussed earlier in this paper, the coking characteristics of coal are quite important in the determination of the suitability of the coal for small stokers. To widen the range of choice of coals, manufacturers have designed agitating devices to break up the coke as it is formed in the bed and prevent the formation of large masses that might occasion difficulties. One of these is a mechanically operated poker that is inserted into the fuel bed from the bottom of the retort at frequent intervals. Another type consists of a short screw extending diagonally upward in the retort from the back to the front. In a report[22], results of a series of burning tests with one of these devices are given; the report presents the disadvantages and advantages of the device and concludes that the principle has merit for coals that are very strongly coking.

Bin-Fed Stokers

The screw-feed principle that is used on practically all of the small stokers not only permits placing the coal hopper at a distance from the firing door of the boiler or furnace that will allow easy access to the furnace but also permits the feeding of coal directly from the bin when desired. Some manufacturers build into the user's bin a hopper-type bottom and others use a rotating transfer screw in a flat-bottom bin to bring the coal to the entrance to the main feed screw. Several variations in the design of equipment are used and coal can even be made to make a right-angle turn in its flow from the bin to the heating unit. As with anthracite, the bin-feed principle has been well worked out and is successfully used in many installations.

Automatic Ash Removal

As previously discussed, the ash remaining from the combustion of the coal deposits on the hearth of the furnace where it sinters or fuses into a clinker that can readily be removed with a pair of clinker tongs. Although this operation is readily done and is normally not necessary more than once each day, it is a feature of operation that prevents the conventional stoker, even with bin feeding, from being completely automatic. The development of a stoker that will remove the ash automatically and place it in a container in the basement or outside the house has received and is receiving the attention of a number of manufacturers. Because of the wide range of clinkering tendencies of the ash of bituminous coals, the attainment of a design that will be satfactory for the entire range of coals is more difficult than for anthracite which has a much narrower range of ash-softening temperatures. One manufacturer, a subsidiary of a coal producing company, has, however, had on the market for a number of years a stoker that includes the principles of bin feeding and automatic ash removal. In the distribution of this stoker, it is restricted to the use of coal specified by the manufacturer; this method has simplified the problem of obtaining satisfactory performance.

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[20] Performance of Automatic Air Controls for Small Underfeed Stokers, by H. R. Limbacher. (*Heating and Ventilating*, Vol. 35, 1938, p. 40-42).

[21] Loc. Cit. See Note 12.

[22] Loc. Cit. See Note 12.

Controls for Stokers

Controlling devices that will govern the operation of the stoker to maintain a fuel bed in condition to respond to a demand for heat, transmit the demand for heat to the stoker, and prevent overruns of temperature are essential accessories to a stoker-fired heating plant. The normal controls furnished are (1) a thermostat in the living quarters to start the stoker directly or through a relay as the room requires heat or to stop it when the requirements are satisfied, (2) a device to operate the stoker at such intervals as required to maintain a fuel bed when heat is not required, and (3) a limiting device to prevent rates of heat liberation greater than can be transferred to the space to be heated.

Thermostats operating from room temperatures are the usual type for this service as used on hand-fired furnaces and oil and gas burners and require no comment. They include the heat anticipating and accelerating types.

The most frequently used device to maintain a fire is a time switch that operates the stoker for a few minutes at half-hourly or hourly intervals. This is not wholly satisfactory as coals vary in the length of operating period required to maintain a suitable fuel bed and even with one coal the length of the period varies from time to time. Combinations of time switches to turn the stoker on with a stack switch to turn it off when some set temperature has been reached have been used. These have not been completely satisfactory because the thermostatic elements do not retain their calibration when overheated or heated for long periods at high temperatures. Modifications that include a stack thermostat that turns off the stoker when a certain temperature rise rather than a certain temperature has been attained have been proved to have merit and a thermostat mounted in the door of the firebox to respond to furnace temperature has also been found suitable.

Limiting devices to prevent overruns of temperature that will damage the furnace or boiler or overheat the space are essential on stokers as on other types of firing equipment. The fact that a large mass of incandescent fuel may be left in the bed at the time the room thermostat is satisfied is conducive to overruns as this bed continues to radiate to the heat-absorbing surfaces of the combustion space. Stack or firing-door thermostats, aquastats, pressurestats, and bonnet thermostats all have been used as limiting devices for this service.

Thermal Efficiencies

The thermal efficiency of a stoker-boiler or stoker-furnace combination is of less importance to the homeowner than the degree of attention-free and trouble-free operation, but any calculations of cost of heating for any comparative purposes will depend on this factor which is of interest particularly to the heating and ventilating engineer. No general statements of the efficiency to be expected are of great value as the overall efficiency is as much a function of the boiler or furnace as it is of the stoker.

The values of 65 per cent for stokers burning less than 100 lb of coal per hour and 70 per cent for those larger that have been suggested by the *Stoker Manufacturers Association* have been cited. Yancey[23] reported overall efficiencies of a hot-water boiler fired with an overfeed stoker of 64 to 77 per cent for both continuous and intermittent operation when burning weakly coking coals suitable to the type of stoker. Cleghorn[24] obtained efficiencies of 50 to 67 per cent with an underfeed stoker and a steam boiler; variations were caused by the type and rate of operation and the type of coal. Sherman and Cross[25] give the results of field tests conducted on underfeed stokers in a hot-water and a steam boiler and a warm-air furnace with the conclusion that a normally expected efficiency for the average conversion installation with average adjustment may be 55 per cent.

The factors that will govern the efficiency that will be obtained are the excess air maintained and the effectiveness of heat absorption in the heat-transfer surfaces of the heating equipment. If the heat-absorbing surfaces are not ample for the rates of heat liberation used, the stack temperatures will be high and the efficiency low even if a low excess air is maintained. On the other hand, adjustment of the air supply to excessive values will result in low efficiencies. The loss due to combustible in ash is practically nil with the clinkering type of stoker and losses due to unburned gaseous combustible in the flue gases should also be negligible. With properly coordinated heat-absorbing surfaces and rates of heat liberation and with an excess of air during operating periods of 50 to 60 per cent, corresponding to 10 to 11 per cent CO_2, efficiencies of 65 to 70 per cent should be obtained.

Future Stoker Market

Of heating plants of every type above the residential size, it may be safely said that they may be included in the prospective stoker market where coal is available at prices competitive with other fuels. This is true because the possible savings due to the use of coal on a stoker over hand firing or over oil or gas in fuel alone or fuel plus labor will pay for the cost of the firing equipment.

Of residential heating plants, however, this is not true because the smaller the heating plant the more difficult it becomes to show a saving great enough to pay for the stoker. The cost of the stoker does not decrease at the same rate as the amount of fuel saved decreases. For example, assuming that the efficiency obtained with

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[23] Loc. Cit. See Note 5.

[24] Loc. Cit. See Note 17.

[25] Efficiencies and Costs of Various Fuels in Domestic Heating, by R. A. Sherman and R. C. Cross. (Tech. Report No. 3, *Bituminous Coal Research, Inc.*, 1936).

Table 2—Distribution of Heating Methods in 1- and 2-Family Urban Homes of the United States, at Close of 1936

HEATING METHOD	NUMBER	PER CENT
Stove heated	6,547,658	45
Hand-fired coal furnace	5,926,263	40
Automatically-fired		
Oil	1,349,401	9
Gas	639,536	4
Stoker	219,403	2
Total	14,682,261	100

hand-fired bituminous coal is 45 per cent and that with a stoker is 60 per cent, a saving of 25 per cent of the fuel should be possible. Actually, on the small plant, the amount of coal used may not decrease because due to the greater ease of obtaining heat more heat will be used. If, however, the saving of 25 per cent is assumed, this will amount on a house using 8 tons of coal at $8 per ton to $16 per year. The stoker may be assumed to cost $250 installed; with fixed charges of 15 per cent, the annual charge is $37.50. The net cost to the owner for the convenience and comfort of the stoker is $21.50 per year.

Although this premium for improved heating is less, in most localities, than for other fuels, it shows that the market for stokers is governed by the ability of the customer to buy. The percentage of the potential customers sold will depend on the merchandising ability of the industry.

No complete analysis of the potential market will be attempted in this paper because a survey for the entire country should be a summation of analyses for each city rather than from average figures for the entire United States. The data for individual cities were not available. Some conception of the possible market can, however, be gained from the data for the entire nation.

Data given in Table 2 show distribution of heating methods in 1- and 2-family urban homes of the United States.

On the basis of ability to buy, it is seen that of the present homes those heated by stoves can be dismissed as prospects. The entire remainder cannot be considered as prospects as this will depend on their income. Mean values of family incomes from the Brookings Institute 1929 survey and from the Federal Income Tax Returns of 1933 as accepted by the *American Gas Association*[26] in a survey on the economics of gas househeating showed that 25 per cent of the families had incomes greater than $2200 annually.

If it is assumed that families with incomes of $2200 or more can afford to pay the $21.50 annual premium for stoker-fired heating, then 25 per cent of the homes may be included in the potential stoker market. This amounts to 3,670,565 prospects. If this lower limit of income is correct, then all above can be considered as prospects on the basis of income for, as previously pointed out, the premium for stoker heating decreases as the size of the house and amount of fuel used increase. The potential market for competitive fuels is more limited than that for stokers because, in most districts, a premium for the oil or gas must be paid over hand-fired coal in addition to the fixed charges on the equipment.

From the total potential market must be deducted those already supplied with automatic heating leaving a balance of 1,462,225. This figure must also be adjusted by deduction of those homes that are in the far west and southwest where coal is not a competitive fuel and by an addition on the logical assumption that many of those installations now using oil and gas are prospects for stokers. No attempt has been made to make these adjustments.

The figures given include all 1- and 2-family homes whether owner-occupied or rented. Rented homes are prospects for stokers as well as owner-occupied homes although the sales effort required is undoubtedly greater.

This brief discussion of the market for stokers does not give any conclusive figures but it does show the method that should be used in each district to determine the sales possibilities. It indicates that the market for conversion installations in present homes is not limitless and may reach saturation within a relatively few years. Stokers at lower cost will extend the range of incomes that may be included in the market and more stokers that are fully automatic will increase their sale in that market that demands this type of operation.

The ultimate market for stokers has not been reached for new homes. Those new homes in which boilers and furnaces specifically designed for oil or gas are installed are quite definitely removed from the stoker market. However, a more conventional boiler or furnace fired with a stoker offers the owner the advantage that later conversion to other fuels is possible for the cost of the burner if circumstances should warrant the change.

Summary

This paper has not attempted to cover fully the information that a heating and ventilating engineer should have on the subject of small stokers designed for burning bituminous coal. It has rather attempted to point out the highlights and include references to recent literature that will give those who require it the complete information required to insure satisfactory installations of this economical method of heating.

Plan Standardization of Coal Stokers

The *American Standards Association* has been asked by Consumers' Counsel of the National Bituminous Coal Commission to develop standards for coal stokers. The Advisory Committee on Ultimate Consumer Goods by the National Consumer-Retailer Council at its April 19 meeting proposed that this project should more properly be considered by the Mechanical Standards Committee, and accordingly referred the proposed project to the MSC.

In transmitting its suggestion the Consumers' Counsel of the National Bituminous Coal Commission also remarked, "As an agency established to safeguard the interests of consumers in the federal regulation of the bituminous coal industry, we are interested in this subject. Consumers of coal should be, and undoubtedly are, concerned not only with the price they pay for coal but also with burning equipment which will give them efficient heating results. On this score, you may be familiar with the enclosed Uniform Stoker Rating pamphlet, issued by the *Stoker Manufacturers Association*."

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[26] A Study of the Economics of Gas Househeating, by A. M. Beebee. (Report of the Househeating and Air Conditioning Committee, *American Gas Association*, April, 1936).

On to Mackinac!

A CONCENTRATED program of business and pleasure that will appeal to every Society member has been announced by the Committee on Arrangements for the Semi-Annual Meeting at The Grand Hotel, Mackinac Island, Mich., July 4-6.

Final plans were completed at a committee meeting May 13 when members of the host chapters approved the program and received reports from other local chapters which indicated unusual interest in and enthusiasm for the Mackinac meeting with the prospect of a record attendance.

The program has been carefully planned for a two day business session, July 5 and 6, with three technical meetings and at least nine papers. July 4 will see the Council in session and some special committee meetings, but for others present the day has been set aside largely for a sports program that will appeal to members, ladies and children.

Routes to Mackinac are varied and there are round-trip summer excursion fares for those traveling by train, combination rail and boat fares, and fine roads for motorists.

The trip to Mackinac need not be expensive because there are so many combinations of routes that can be chosen. The time required can be adjusted to suit the business man or the member who desires a few days vacation with his family. Select a fast schedule or a leisurely one.

Here are some typical examples:

1. Motor or train to Buffalo, then boat direct to Mackinac *or* motor to Buffalo, boat to Detroit and motor to Mackinaw City. (For Boston, New York and Philadelphia members.)

2. Motor or train to Cleveland then direct boat to Mackinac. (For Pittsburgh, Cincinnati and members from southeast.)

3. Train direct to Mackinaw City, return by boat to Detroit, Chicago, Cleveland, Buffalo *or* boat from any of these cities on going trip, returning direct by train. (For eastern, southern or western members.)

4. Motor to and from Mackinac. (Entrance and ferry service from Mackinaw City and St. Ignace. Parking facilities at each city, speed cruiser and steamer service to Island, running time 20 to 40 minutes.)

5. Motor to Wisconsin ports, Milwaukee, Manitowoc, or Kewaunee—steamer to Michigan ports, Muskegon, Ludington, or Frankfort—then motor to Mackinaw City.

6. Motor to Chicago, then boat direct to Mackinac.

Consult motor club and local travel agent for best routes and lowest rates on train or boat.

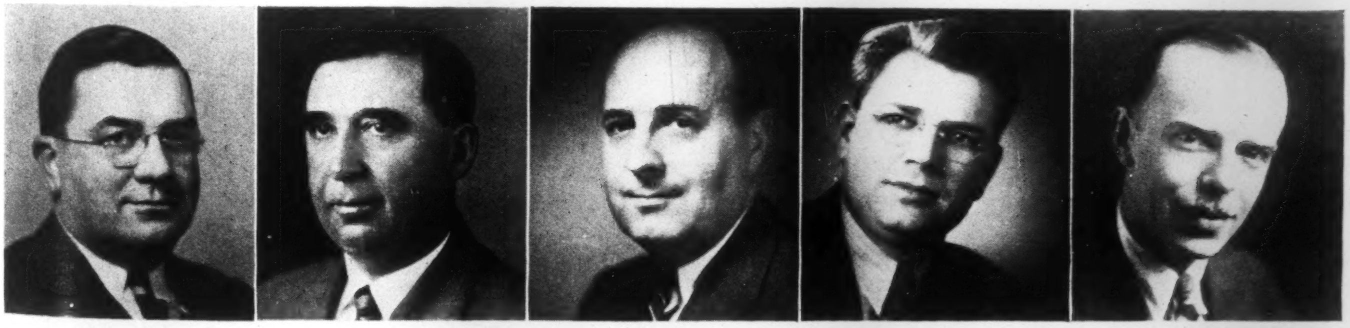
For the convenience of members en route to Mackinac, there will be greeters committees and reception headquarters June 30 and July 1 at Buffalo, Cleveland, Detroit in the Hotel Statler, and in Chicago at the Palmer House. Representatives of the local chapters will be pleased to render any possible service to visiting members. Inquire for the headquarters of Western New York (Buffalo), Northern Ohio (Cleveland), Michigan (Detroit) and Illinois (Chicago) chapters.

"On to Mackinac" is the slogan of the host chapters and C. R. McConner, Kalamazoo, and F. J. Linsenmeyer, Detroit, appointed a committee to handle the arrangements directed by Wm. G. Boales, General Chairman.

All events on the island will be in charge of O. D. Marshall, Grand Rapids, and activities en route on the steamers *South American* and *North American* will be directed by Frank Feely, Detroit, and Tom Brown, Chicago.

The committee chairmen are: *Reception*, T. L. Osberger, Grand Rapids; *Ladies*, Arthur Boot, Grand Rapids; *Sports*, B. F. McLouth, Lansing; *Transportation*, H. F. Reid, Muskegon; *Sessions*, W. W. Bradfield, Grand Rapids; *Boat Trips*, C. H. Pesterfield, East Lansing; *Golf*, G. D. Winans, Detroit; *Banquet*, L. G. Miller, East Lansing; *Lake Fishing*, S. H. Downs, Kalamazoo; *Children's Program*, Mrs. Frank Feely, Detroit; *Publicity*, T. D. Stafford, Grand Rapids; *Chapter Attendance*,

Hosts at Mackinac



F. J. Feely W. C. Randall O. D. Marshall B. F. McLouth Tom Brown

F. C. Warren, Grand Rapids; *Finance,* C. R. McConner, Kalamazoo.

These members are your hosts and they await your arrival at Mackinac with pleasure and have a keen interest in making your stay on the island enjoyable. Mackinac offers much of historic interest as well as the opportunity to meet members from all parts of the country and to hear speakers and discussions on subjects of vital importance in the field of heating, ventilating and air conditioning.

It is advisable to make reservations early for hotel, boat and train accommodations for an enjoyable trip to Mackinac.

Headquarters for the meeting are at The Grand Hotel and special American plan and European rates are available. In addition, there are the following nearby hotels with European plan rates from $2.00 to $4.00 per day single, and $3.00 to $6.00 per day double: Windsor, Windermere, Iroquois, Lakeview and Cloghaun.

A detailed program of events is shown and plans should be made to join your friends and fellow members at Mackinac July 4, 5 and 6.

Program—Semi-Annual Meeting 1939

The Grand Hotel, Mackinac Island, Mich.—July 4-6, 1939

July 4

8:30 a.m. Registration
9:30 a.m. Golf Tournament (Greens Fee $2 per day), Hotel Course and Country Club Course
10:00 a.m. Council Meeting
10:30 a.m. Children's Sports Program
11:30 a.m. Bicycle Party (35c per hour charged for bicycle rental)
1:00 p.m. Fishing Party
1:30 p.m. Golf Tournament—No charge for transportation between Hotel Course and Country Club Course for tournament players
2:00 p.m. Soft Ball Game
3:00 p.m. Meeting—Committee on Research
3:00 p.m. Children's Hiking Party
3:30 p.m. Water Sports at Pool (fee for bathers, 75c)
6:00 p.m. Social Hour (Dutch Treat Club, $1.00 per person —Blue Room)
7:30 p.m. Meeting—Guide Publication Committee
8:30 p.m. Keno or Movies
10:00 p.m. Dance and Floor Show (Casino)

July 5

9:00 a.m. TECHNICAL SESSION
  Call to order
  Greetings
  Response by Pres. J. F. McIntire
  Review of Society activities by President McIntire
  Heating Low-Cost Homes, by L. E. Seeley and R. K. Thulman
  The Effect of Vibration Upon Free Convection, by R. C. Martinelli and L. M. K. Boelter
  Evaluating Performance of Water Heaters Fired with Solid Fuels, by H. J. Rose and R. C. Johnson
10:00 a.m. Children's Sports
11:00 a.m. Carriage Ride Around the Island ($1.50 per person)
12:00 noon Meeting—Nominating Committee
1:30 p.m. TECHNICAL SESSION
  Report of Finance Committee, by A. J. Offner
  Report of Membership Committee, by E. K. Campbell, Chairman
  Ozone in Ventilation, by W. N. Witheridge and C. P. Yaglou
  Effect of Size and Type of Air Inlet and Outlet on the Heat Output of Convectors, by A. P. Kratz, M. K. Fahnestock and E. L. Broderick
  A Theory Covering the Transfer of Vapor Through Materials, by F. B. Rowley
  Fire Protection for Air Conditioning Systems, by R. C. Loughead
2:15 p.m. Boat Ride (50c per person—steamer leaves Union Dock)
4:30 p.m. Tea Dance and Concert in Tea Garden
7:00 p.m. Semi-Annual Banquet and Dance

July 6

9:00 a.m. TECHNICAL SESSION
  Report of Committee on Research, by W. L. Fleisher, Chairman
  Summer Cooling Requirements in Different Metropolitan Districts with Special Reference to Washington, by F. C. Houghten, F. E. Spurney and Carl Gutberlet
  Study of Summer Cooling in the Research Residence for the Summer of 1938, by A. P. Kratz, S. Konzo, M. K. Fahnestock and E. L. Broderick
  Performance of Cooling Towers, by B. M. Woods and L. M. K. Boelter
  Unfinished Business
  New Business
  Resolutions
  Adjournment
10:30 a.m. Hiking Party to Fort Mackinac and Visit to State Museum
1:30 p.m. Informal Golf Matches
1:30 p.m. Ladies Bridge
2:00 p.m. Horseback Riding ($1.50 per hour)
  Boardwalk Stroll and Ladies Shopping Tour

Method of Choosing Location of, Financing and Conducting Meetings of the Society

Resolved: That inasmuch as the Annual and Semi-Annual Meetings of the Society come under the jurisdiction of the Council, the following rules governing the handling of such meetings be adopted by the Council and published in the JOURNAL of the Society at least twice during every year, preferably just prior to each meeting.

1—The Council will select the city in which the Annual or Semi-Annual Meeting is to be held, giving due consideration to the invitations received from Chapters or members as well as to the advisability of so distributing those meetings as to make them of the greatest advantage to the general membership, and to reduce as far as possible the expense of members attending.

2—That an appropriation be made to cover the entertainment or local expenses, incurred in connection with the meeting not exceeding $500.00, the regular meeting expense to be taken care of by the General Fund of the Society in the regular way.

3—That no registration fee or compulsory obligations of any nature be imposed on members or guests.

4—That the purchase of tickets for banquets or for any other form of entertainment that may be provided be entirely voluntary.

5—That the grouping of features and the sale of tickets for group features be discouraged.

6—That the raising of funds from manufacturers of heating apparatus be discouraged.

7—That the display of samples, or of literature, advertising the product of any manufacturer in any way, shape or form, be not permitted at the booths, registration desk, or in or about the meetings.

8—That the distribution of trade papers be entirely at the discretion of the committee in charge.

9—That the local Chapter or local members, be empowered to form a General Committee with such sub-committees as may be required to handle the details of transportation, hotel accommodations, entertainment, finance, etc., and that this General Committee be requested to confer frequently with the Council, through the Secretary of the Society, and to make frequent reports on progress in connection with the various matters being handled by them.

10—That the arrangements of elaborate and costly entertainment features be discouraged.

Adopted at Council Meeting, January 29, 1926.

Mackin-aw *or* Mackin-ack?

A Grand Meeting Place

By Jennette McColl

Miss McColl

Although it is only on clear days, with the wind in the right direction, that we are sure of spelling "thermodynamics" correctly, nevertheless, that little moth-hole in our education doesn't prevent us from feeling like a charter member of the ASHVE. We have lived, breathed and talked the Society for so many years—and even attended several of its meetings.

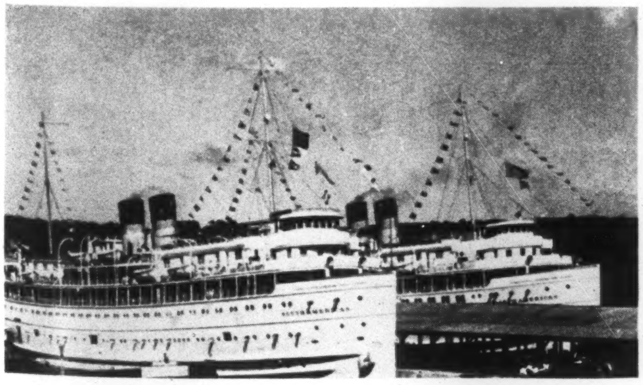
Now, we hear, you all will journey northward to Mackinac Island for a gala Fourth of July (July 4, 5 and 6) on that historic ground. There will be the usual busy technical discussions in the mornings, the scurryings about for golf games, fishing trips and hikes through the woods in the afternoon and the prolonged evening arguments as to whether it is pronounced Mackin-aw or Mackin-ack. (We heard one exhausted soul say, "All right, all right, I get it. The island is called Mackin-aw but they won't let me drive my Cadill-aw on it.")

The meeting promises to be doubly interesting because J. F. McIntire, president of the Society, will have the fun of presiding over the sessions right in his own back yard, as it were. Meanwhile, the several chapters which hover on the edge of the Great Lakes are coöperating with the host chapters, Michigan and Western Michigan, to show the visitors from the north, east, west and south what gorgeous scenery, interesting history and even more interesting people may be found in this Great Lakes region.

The Grand Hotel will be the headquarters for the meeting, which is titled the Great Lakes Summer Meeting. Those two blocks of pillared veranda overlooking the Straits of Mackinac are going to lure Society members out into the sunshine the minute the technical sessions adjourn. So is the gleaming white fort up on the bluff.

So many diversions are right there for the asking that the problem will be a matter of selection. In an island world of your own, two and one-half miles long and two and one-half miles wide, there is the nine mile hike around it, for instance, or the deep lake trout fishing, boating of every description, swimming, two nine-hole golf courses to conquer, carriages and horseback rides through woodsy lanes (you'll have to leave your car over on the mainland).

The Committee on Arrangements is providing a summer meeting which will be the chief topic of conversation all next winter, we guarantee. Oh boy, I hope I can go.



OLD
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Panel Heating Development Described at Montreal Meeting

March 20, 1939. A Montreal Chapter meeting was held at the *M.A.A.A* with an attendance of 29 members and guests, who were called to order by Pres. F. J. Friedman at 8:00 p. m. A welcome to the guests was extended on behalf of the Chapter by President Friedman.

The guest speaker of the evening, L. L. Munier, New York, N. Y., was introduced and addressed the Chapter on the subject of The Development of Panel Heating in America. Mr. Munier discussed radiant heating versus convection heating, giving relative costs of installation and operation of these systems. The talk was illustrated with a film showing fabrication of coils and installation of panel heating.

After Mr. Munier's talk, an open discussion was held until the meeting adjourned at 10:15 p. m., according to the report of Secy. C. W. Johnson.

Residential Air Conditioning Subject of Joint Meeting at Buffalo

April 10, 1939. A joint meeting of the Buffalo Air Conditioning Council and the Western New York Chapter ASHVE was held, both organizations being guests of the Iroquois Gas Corp. The minutes of the previous meeting were read and approved.

Pres. J. J. Landers appointed the following committee to work in conjunction with a similar committee from the Air Conditioning Council to formulate the heating and ventilating section of the new Municipal Building Code: W. R. Heath, H. C. Day, W. S. Eisele, M. C. Beman and H. C. Schafer.

Nominations for Chapter officers for the year 1939-40 as prepared by the Board of Governors were adopted without any additional nominations being offered.

President Landers appointed the following Auditing Committee to report at the May meeting: B. C. Candee, W. E. Voisinet and P. S. Hedley.

C. W. Farrar described in detail plans for the Society's Semi-Annual Meeting at Mackinac Island, July 4-6.

The meeting was then turned over to the Air Conditioning Council and at the conclusion of their business session, President Landers introduced the speaker of the evening, Miss Margaret Ingels, technical adviser to the advertising department of Carrier Corp., Syracuse, N. Y. Miss Ingels chose as her subject, Residential Air Conditioning, and explained various systems available for both summer and winter air conditioning of homes. The talk was well received by the members who had many questions for Miss Ingels, and a large number of the group joined in the discussion of domestic air conditioning, according to the report of Secretary Heath.

North Carolina Chapter Holds Organization Meeting and Elects Officers

April 21, 1939. The organization meeting of the North Carolina Chapter of the ASHVE took place at the King Cotton Hotel, Greensboro, N. C., at 4:00 p. m. and was called to order by the temporary chairman, Prof. R. B. Rice, who had been elected to serve in this capacity at a previous meeting held in Burlington on December 2, 1938. At this time Professor Rice announced that among those present were J. H. Walker, Detroit, member of the ASHVE Council and vice-chairman of the Committee on Research, and A. V. Hutchinson, New York, secretary of the Society.

Arrangements for the meeting were in charge of Messrs. Harding, Reed and Petty. Among those present were the following members: R. B. Rice, E. R. Harding, T. C. Cooke, H. H. Hill, Arvin Page, W. E. Gray, L. L. Vaughan, C. C. Cornwall, J. G. Muirheid, C. E. Petty, H. L. McDowell, William Wallace, II, Harry Hoffman, James Marshall, F. E. P. Klages, G. C. Burr and F. H. Oertel. Some of the guests attending were P. L. Guest, Jr., W. H. Sullivan, Sr., Mr. Page, Robert Kerman, R. U. Sish, W. B. Truitt and Wallace Truitt.

Chairman Rice gave a report of the Chapter activities with which he had been occupied during the past few months, most of which had been directed towards the present meeting, and coordination of the work of the various temporary committees which had been appointed.

T. C. Cooke, temporary secretary, told of the work which had been accomplished since the first meeting, which consisted chiefly of corresponding with newly elected members of the Society and inviting them to affiliate with the Chapter, as well as keeping members posted on activities. It was noted that several of these new members had responded and were present.

Professor Rice then presented to the group messages of congratulations from officers of the ASHVE, as well as officers of other Chapters throughout the United States and Canada. Messages were received from the following and read to the meeting: Pres. J. F. McIntire, First Vice-Pres. F. E. Giesecke, Second Vice-Pres. W. L. Fleisher, Treas. M. F. Blankin, Past Pres. E. Holt Gurney, J. R. Vernon, Illinois, H. M. Hendrickson, Southern California, F. J. Friedman, Montreal, C. L. Templin, Atlanta, E. W. Gray, Oklahoma, H. H. Erickson, Philadelphia, H. G. Meinke, New York, R. D. Morse, Pacific Northwest, J. J. Landers, Western New York, C. R. McConner, Western Michigan, William Worton, Manitoba, S. P. Eagleton, Washington, D. C., the Golden Gate Chapter, E. O. Eastwood, member of the Council, and W. E. McDowell, president of the North Carolina Engineering Council. On motion of Mr. Wallace, seconded by Mr. Petty, it was voted that these messages should be acknowledged by the Secretary.

The Membership Committee reported that since the December meeting seven new members had been secured in the State, which was gratifying news. This announcement was made by Mr. Harding, who acted as chairman of the Membership Committee with all other members assisting.

A report of the By-Laws committee was called for and By-Laws and Rules were presented to the chairman for reading to the Chapter by Mr. Harding. Mr. Wallace made a motion, seconded by Professor Vaughan, that these Rules and By-Laws for Chapter operation be accepted as read. This motion was voted upon and unanimously carried. The By-Laws Committee previously appointed consisted of Professor Vaughan, Mr. Wallace, Mr. Harding, and F. F. Bahnson.

It was brought out by Mr. Wallace that the Chairman should appoint a Nominating Committee consisting of the two acting chair officers, augmented by three additional men. Professor Rice appointed Professor Vaughan, and Messrs. Harding and Petty to complete the Nominating Committee.

Upon completion of these appointments, the assembled meeting was recessed and the Nominating Committee went into session in order to select nominees for Chapter officers.

When the meeting was again called to order, Professor Vaughan, who had acted as chairman of the Nominating Committee, presented the following proposed nominees:

President—R. B. Rice
Vice-President—E. R. Harding
Secretary-Treasurer—T. C. Cooke
Board of Governors—H. H. Hill, Arvin Page, W. E. Gray.

A motion was made by Professor Vaughan, and seconded by Mr. Burr that the nominations be closed. This motion was carried unanimously and the officers were duly elected for the ensuing year.

Announcement was made by President Rice that the Chapter had been asked to affiliate with the North Carolina Engineering Council, and Professor Vaughan, who has been actively identified with the Council for many years, gave a very interesting talk on its work.

Secretary Hutchinson was introduced by President Rice and told North Carolina members of plans for the Society's Semi-Annual Meeting at Mackinac Island, Mich., July 4-6. A rising vote of thanks was given to Mr. Hutchinson for his assistance in the organization of the Chapter as well as his attendance at meetings.

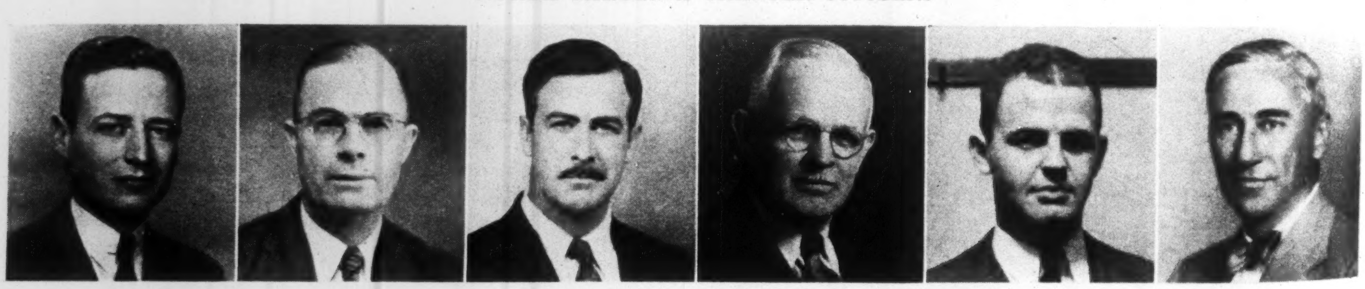
It was mentioned that inasmuch as the *North Carolina Society of Engineers* was holding a meeting at Wrightsville Beach on the weekend of July 15, it might be well for the Chapter's next quarterly meeting to be held there at that time. The decision on this matter was to be announced at a later date.

The session then recessed until re-assembly at dinner.

Immediately following dinner, President Rice advised that there was still the matter concerning the North Carolina Engineering Council to be decided, and a motion was made, seconded and carried that the Chapter affiliate with the State Council. It was moved by Professor Vaughan that the Chapter elect representatives as follows: *Representatives*—R. B. Rice (one year term), T. C. Cooke (two year term); *Alternates*—H. H. Hill (one year term), Arvin Page (two year term). This motion was seconded and carried unanimously and the Secretary was advised to send the necessary fee to the North Carolina Engineering Council with a letter certifying the representatives.

On behalf of the ASHVE and the members of the Council, Secretary Hutchinson presented to the North Carolina Chapter

NORTH CAROLINA CHAPTER OFFICERS



H. H. Hill
Board of Governors

W. E. Gray
Board of Governors

R. B. Rice
President

E. R. Harding
Vice-President

T. C. Cooke
Secretary-Treasurer

Arvin Page
Board of Governors

their charter, which had been granted by the Council, and which was received by President Rice.

With an appropriate introduction, Professor Vaughan presented J. H. Walker, engineering assistant to the general manager, Detroit Edison Co., who was the speaker of the evening and gave an illustrated lecture on Air Conditioning a Glass Brick Building. This talk was based on the construction and air conditioning of the new office building of Detroit Edison Co. Of particular interest was the section devoted to air distribution, the maintenance of definite static pressures at given points in the system, and the intricate mixing dampers provided for control of room temperatures. Another noteworthy feature was the fact discussed by Mr. Walker that the parts of the building which were not glass were made of a brick which was largely composed of fly-ash from the pulverized fuel plants.

At the conclusion of the talk, several members questioned Mr. Walker concerning the system and construction of the building and a lively discussion lasted for approximately 30 min.

Mr. Walker was given a rising vote of thanks and the meeting was adjourned until the July meeting.

Western Michigan Chapter Discusses Proposed Ordinance

April 24, 1939. A meeting of Western Michigan Chapter was held at the Browning Hotel, Grand Rapids, and dinner was served at 6:45 p. m. to 18 members and 14 guests.

Pres. C. R. McConner called the meeting to order and after roll call by Secy. W. G. Schlichting, minutes of the February and March meetings were read and approved.

The Nominating Committee, consisting of W. W. Bradfield, O. D. Marshall and L. G. Miller, presented the following names for officers for the 1939-1940 season:

President—B. F. McLouth
Vice-President—T. D. Stafford
Secretary—C. H. Pesterfield
Treasurer—C. H. Morton
Board of Governors—C. R. McConner, W. G. Schlichting and F. C. Warren.

President McConner asked for additional nominations from the floor, and, when there was no response, the nominations were closed.

By vote of the members present, the sum of $70.00 was appropriated toward expenses for the annual meeting in May and the summer meeting at Mackinac.

The remainder of the meeting was given over to a discussion of the suggested ordinance prepared by the National Board of Fire Underwriters. Members of the Chapter's Heating and Ventilating Code Committee and R. E. Seeger, city engineer, reviewed the subject and the following suggestions and revisions to the proposed ordinance were made.

1. Classification of installations should not be made on a cfm basis, but rather for the occupation or usage of the space to be treated.
2. An appendix should be included in the ordinance, defining all terms (i.e., fire doors, fire dampers, fire exposure, etc.) and giving specifications as to minimum construction requirements. Terms should be in agreement with accepted standards as set forth in The Guide of the ASHVE.
3. Section 4C should be clarified to cover the possible case where a vertical duct changes to a horizontal run.

Mr. Rockafield of Kalamazoo, a representative of the Michigan Roofing and Sheet Metal Contractors, discussed the pending Michigan State Bill and suggested that members interested attend the meeting scheduled for April 26.

The meeting adjourned at 10:45 p. m., according to the report of Secretary Schlichting.

March 29, 1939. Western Michigan Chapter met at Michigan State College, East Lansing, Mich., at a joint meeting with the Michigan Chapter of the Society, and also in conjunction with the Eighth Annual Forced Warm Air Conference. Dinner was served at 6:45 p. m. in the Union Building to approximately 225 and among this number were 20 members of Western Michigan Chapter.

Pres. C. R. McConner presided and after roll call by Secy. W. G. Schlichting, all regular business was dispensed with until the April meeting.

B. F. McLouth served as toastmaster and introduced F. J. Linsenmeyer, president, and G. H. Tuttle, secretary, of Michigan Chapter, who responded briefly. Others who gave short informal talks included Dean H. B. Dirks, Prof. L. G. Miller, Prof. S. Konzo, F. R. Bishop, E. B. Root and Professor Ruehling.

Sgt. Ray Sullivan of Michigan State Police gave an interesting sharp shooting exhibition and discussed the several weapons used by that organization.

Prof. L. G. Hayes of the Dairy Dept., Michigan State College, presented a comedy sketch.

C. A. Paquin, chief of Division of Education and Public Relations for the State of Michigan, gave an illustrated address, entitled Scenic Michigan.

W. G. Boales, Detroit, spoke briefly of plans for the ASHVE Great Lakes Summer Meeting, after which the meeting adjourned at 11:00 p. m.

Oregon Members Hosts To Pres. McIntire

ASHVE members in Portland, Oregon, and vicinity are enthusiastic about their recent meeting with Pres. J. F. McIntire, who visited them while on a western trip to Society Chapters.

At a dinner held in honor of Mr. McIntire in the Castilian Room of the Heathman Hotel, Portland, on April 27, almost all Society members and those who have applied for membership from this area were present. Mr. McIntire gave an address on The Birth of Air Conditioning and Its Future, which was of interest to the group. In addition, he outlined some of the activities of the Society, the features of cooperation between the national organization and local Chapters, and answered many questions in regard to the procedure for petitioning for a charter.

B. W. Farnes was master of ceremonies and other speakers were Fred DeTemple, of the *Heating, Piping and Air Conditioning Contractors Association*, and J. D. Kroeker, consulting engineer. Arrangements for the meeting were in charge of H. K. Mead and Mr. Kroeker.

Atlanta Chapter Hears About Financing of Building

April 4, 1939. The regular meeting of Atlanta Chapter was called to order by Pres. C. L. Templin at 8:00 p. m. at the Biltmore Hotel. Roll call recorded 18 members and nine visitors present. The minutes of the previous meeting were read and approved, following which reports of officers and committees were in order.

The treasurer announced that receipts and disbursements were brought up to date and he was asked to issue new membership cards immediately.

An interesting outline was given by Vice-Pres. S. W. Boyd of the arrangements for the Society's Semi-Annual Meeting at Mackinac Island, July 4-6.

On motion duly made by C. T. Baker, seconded by Mr. Boyd, the proposed amendments to the By-Laws were unanimously approved.

The application of a new member was reported by the Membership Committee.

The Entertainment Committee pointed out that they were having some difficulty in obtaining speakers. They suggested a joint meeting with the *AIEE* for an important selective speaker at a special meeting. Upon motion duly made and seconded it was decided to hold the joint meeting, but the matter of the Atlanta Chapter supplying a speaker was referred to the Entertainment Committee for handling and a report at the next Chapter meeting.

The Chair was asked to assign various parts of this report for committee investigation and those so designated were instructed to investigate and bring their findings to the next meeting.

One of the Society's Life Members, J. A. Donnelly, Largent, W. Va., was in attendance and spoke briefly on the work which he had been doing and invited all present to the Atlas of Agriculture in the mountains of West Virginia.

R. L. Sweigert of the *ASME* outlined a plan adopted at a recent joint meeting of the local chapters of the *ASME, ASCE, ASEE* and ASHVE for student help in the selection of a professional education. An advisory board has been organized to consult with high school seniors and their parents on any questions which may come up or on information which may be desired on a professional education and career.

An interesting and instructive talk on Financing the Small Job was given by Dudley Stone, of the Morris Plan Bank, who described present plans of banks to carry on the work originated by FHA. He pointed out certain probable changes in the Federal Housing Act, should it be extended by Congress. According to Mr. Stone, it is the expectation of the financial world that the construction industry will continue to receive the benefits of the Federal Housing Administration on financing the small job regardless of changes which may be made in the Act under which this authority was created.

Secy. T. T. Tucker has reported that there being no further business, the meeting was adjourned.

Moves N. Y. Office to Factory

The New York district office of the General Electric air conditioning department, serving the North Atlantic territory, has been transferred from the General Electric Building, 570 Lexington Ave., New York City, to the general offices and works of the department at Bloomfield, N. J. The move was made to facilitate engineering and order service, shipments, and similar activities, which can be handled with greater dispatch for this territory directly from the factory and general offices. The personnel of the office, under V. E. Daniels, district manager, will remain the same, as will the telephone connections.

S. M. Crocker has been named manager of the air conditioning department of the General Electric Co., effective at once, according to an announcement by C. E. Wilson, executive vice-president of the company. Simultaneously it was announced that the commercial refrigeration activities of the company, now located at Cleveland as part of the appliance and merchandise department, have been relinquished by the latter and assigned to the air conditioning department. The reason given for the transfer was that as the businesses of air conditioning and commercial refrigeration develop, similarities in both trade practices and product part applications have become more definitely apparent, and the need for closer coordination of the two lines has resulted.

Appointed Sales Manager

Nash Engineering Co., South Norwalk, Conn., has announced the appointment of E. A. Mead as sales manager on May 1, 1939, following 14 years of continuous service with the company, the past 10 of which have been in the capacity of assistant sales manager. Mr. Mead's training and experience have fitted him for this new extension of his duties and direction of the factory sales organization.

D. R. Richardson Dies

David Rait Richardson, retired manufacturer of New York and Palm Beach, died at his home in Florida on May 8 after a heart attack.

Mr. Richardson was born in Brooklyn, N. Y., on September 27, 1874, and studied at Andover before entering business in 1898. Retiring from business in December, 1936, he was the third member of his family to serve as president of the 102 year old firm of Richardson & Boynton Co., New York, N. Y., manufacturers of heating and air conditioning equipment. The company was founded in Boston in 1837 and moved to New York 50 years later. The first two presidents were Mr. Richardson's grandfather and father, H. A. Richardson and Henry T. Richardson.

For many years Rait Richardson was an enthusiastic yachtsman, racing his own boat in the New York 30's class. He was a member of Turf and Field, the Manursing Island Club, Rye, N. Y., and the Long Island Country Club, Eastport, L. I., and was a member of the New York Yacht Club until he moved to Florida a year ago. He was elected a Member of the American Society of Heating and Ventilating Engineers in 1915.

With Mr. Richardson at the time of his death was his wife, the former Stella Van Anden. Surviving also are two sons, H. Thomas Richardson, president and director of the firm, and David Rait Richardson, Jr., secretary and director, and a sister, Mrs. Joseph H. Seaman, all of New York.

CANDIDATES FOR MEMBERSHIP

The Constitution of the Society, as now amended, requires the following mode of procedure in voting on applicants for membership in the Society. All applications for membership are to be sent to the Secretary and the names of applicants and their references shall be printed in the next issue of the Journal of the Society or sent to the members in other approved manner as ordered by the Council. When replies are received from references, the Candidate's application shall be submitted to and acted upon by the Committee on Admission and Advancement as soon as possible.

When the Committee on Admission and Advancement has acted favorably upon a Candidate's application and assigned his grade, the Council shall vote upon the election of the proposed Candidate for membership by letter ballot. During the past month 54 applications for membership have been received and the names of these men and their sponsors are published in the following list.

Members are requested to scrutinize the list with care. The Committee on Admission and Advancement, and in turn, the Council, urge the members to assume their share of responsibility of receiving these candidates into membership by advising the Secretary promptly of any whose eligibility for membership is in any way questioned.

All correspondence in regard to such matters is strictly confidential, and is solely for the good of the Society, which it is the duty of every member to promote.

Unless objection is made by some member by June 15, 1939, these candidates will be balloted upon by the Council. Those elected to membership will be notified by the Secretary immediately after election.

CANDIDATES	REFERENCES	
	Proposers	*Seconders*
Adema, G. E., Htg. Contractor, N. M. Adema & Son, Buffalo, N. Y.	W. S. Eisele Joseph Davis	W. R. Heath Roswell Farnham

CANDIDATES	REFERENCES	
	Proposers	*Seconders*
Ainsworth, S. E., Engr., Roche Newton & Co., Lubbock, Tex.	A. D. Houska A. E. Banasik (*Non-Member*)	Frank Clowe (*Non-Member*) H. F. Godeke (*ASME*)
Alben, E. A., Htg. Contractor, Alben Equipment Co., Vancouver, Wash.	B. W. Farnes T. E. Taylor	C. E. Enders C. E. Heinkel
Armstrong, C. E., Chief Engr., Armstrong Heat Control Co., Portland, Ore.	J. D. Kroeker T. E. Taylor	B. W. Farnes J. A. Freeman
Bailey, C. F., Instructor, Mech. Engrg., Mississippi State College, State College, Miss.	A. P. Kratz W. H. Severns	S. Konzo H. J. Macintire (*ASRE*)
Banach, C. J., Chief Draftsman, Johnson Fan & Blower Corp., Chicago, Ill.	K. A. Meyer R. A. Haerle	J. H. Shrock H. M. Shufelt (*Non-Member*)
Banta, G. L., Br. Mgr., The Trane Co., Portland, Ore.	T. E. Taylor C. E. Heinkel	J. D. Kroeker B. W. Farnes
Bates, J. H., Student, Purdue University, West Lafayette, Ind.	W. T. Miller H. G. Venemann (*ASRE*)	L. V. Ludy (*ASME*) H. L. Solberg (*ASME*)
Blaker, A. H., Secy.-Treas., National Korectaire Co., Chicago, Ill.	Tom Brown S. M. Trumbo	J. R. Vernon S. I. Rottmayer
Börton, A. R., Sales & Engrg., John J. Nesbitt, Inc., Pittsburgh, Pa.	R. B. Stanger G. G. Waters	F. C. McIntosh T. F. Rockwell
Braun, C. R., Jr., Student, Carnegie Inst. of Tech., Pittsburgh, Pa.	C. M. Humphreys P. A. Edwards	T. F. Rockwell F. C. McIntosh
Burke, J. H., Engr., Carrier Engrg. Corp., Philadelphia, Pa. (*Reinstatement*)	E. H. Dafter W. L. Yerkes	A. P. Shanklin W. A. Grant
Byrne, J. J., Htg. Engr., Mueller Furnace Sales, Portland, Ore.	B. W. Farnes J. D. Kroeker	C. E. Enders T. E. Taylor
Clark, A. C., Engr., Century Co., Portland, Ore.	B. W. Farnes T. E. Taylor	C. E. Heinkel J. A. Freeman
Como, J. A., Engr., Buckhead Plbg. & Htg. Co., Atlanta, Ga.	E. W. Klein C. L. Templin	T. T. Tucker R. F. Hahn
Dyer, W. S., Htg. Contractor, H. W. Dyer & Son, Battle Creek, Mich.	S. W. Todd, Jr. T. L. Osberger	R. E. Distel H. J. Metzger
Fox, W. K., Supt., Northwest Stove Works, Inc., Portland, Ore.	B. W. Farnes T. E. Taylor	J. A. Freeman C. E. Heinkel
Gehrs, William, Br. Mgr., Johnson Service Co., Portland, Ore.	J. A. Freeman J. D. Kroeker	T. E. Taylor S. D. Peterson
Goehler, E. E., Pres., Vortex Mfg. Co., Portland, Ore.	B. W. Farnes C. E. Heinkel	T. E. Taylor J. A. Freeman
Gowdy, A. C., Estimator & Detailer, Handley Plumbing Co., Columbus, Ohio.	D. H. Wyatt H. R. Allonier	J. D. Slemmons J. F. Oelgoetz
Granke, A. A., Sales Engr., Speakman Co., Wilmington, Del.	B. F. Lownsbery F. H. Gawthrop	M. G. Kershaw G. P. Weatherlow (*Non-Member*)
Hample, H. J., Student, Carnegie Inst. of Tech., Pittsburgh, Pa.	C. M. Humphreys T. F. Rockwell	P. A. Edwards F. C. McIntosh
Hawk, J. K., Engr., General Air Cond. Co., Buffalo, N. Y. (*Advancement*)	W. E. Voisinet W. R. Heath	M. S. Jackson W. S. Eisele
Hill, Edward, Jr., Htg. Engr., Fox Furnace Div., American Radiator Co., San Francisco, Calif.	C. L. Peterson C. E. Bentley	G. M. Simonson James Gayner
Hurwich, S. B., Engr., American Lubricants, Inc., Buffalo, N. Y.	Joseph Davis W. E. Voisinet	B. C. Candee Roswell Farnham
Hutchinson, F. A., Mgr., Repair Dept., C. J. Doughty & Co., Shanghai, China.	C. J. Doughty I. K. Kwan	T. F. Waung C. B. Morrison
Hyde, E. V., Sales, Wood Conversion Co., St. Paul, Minn.	R. E. Backstrom F. B. Rowley	A. B. Algren D. B. Anderson
Johnson, F. W., Pres., Johnson Larsen Co., Detroit, Mich.	F. J. Feely R. K. Milward	E. E. Dubry G. D. Winans
Kliefoth, M. H., Treas., Research Products Corp., Madison, Wis.	George Hall G. L. Larson	D. W. Nelson L. A. Wilson (*ASME*)
Kolb, R. P., Prof. Heat-Power Engrg., Worcester Polytechnic Inst., Worcester, Mass.	A. J. Knight (*ASCE*) F. W. Roys (*ASME*)	G. H. MacCullough (*ASME*) C. M. Allen (*ASME*)
Mabley, T. H., Chief Engr., Mechanical Heat & Cold, Inc., Detroit, Mich.	L. C. Mabley Richard Stites, Jr.	G. H. Tuttle E. H. Clark
MacGregor, C. M., Sales Engr., Portland Gas & Coke Co., Portland, Ore.	J. D. Kroeker J. A. Freeman	T. E. Taylor E. C. Willey
Mattingly, M. F., Sales Engr., Johnson Service Co., Chicago, Ill.	J. R. Vernon R. E. Hattis	Tom Brown I. E. Brooke
McDermott, J. P., Br. Engr., The Trane Co., Portland, Ore.	J. D. Kroeker E. C. Willey	T. E. Taylor C. E. Heinkel
Mead, H. K., Mfrs. Agent, Portland, Ore.	T. E. Taylor J. D. Kroeker	B. W. Farnes C. E. Heinkel
Michaels, M. A., Owner, Mgr., Century Co., Portland, Ore.	B. W. Farnes T. E. Taylor	C. E. Heinkel J. D. Kroeker
Moore, B. W., Mgr., Htg. Dept., F. B. Connelly Co., Portland, Ore.	J. D. Kroeker B. W. Farnes	C. E. Heinkel T. E. Taylor